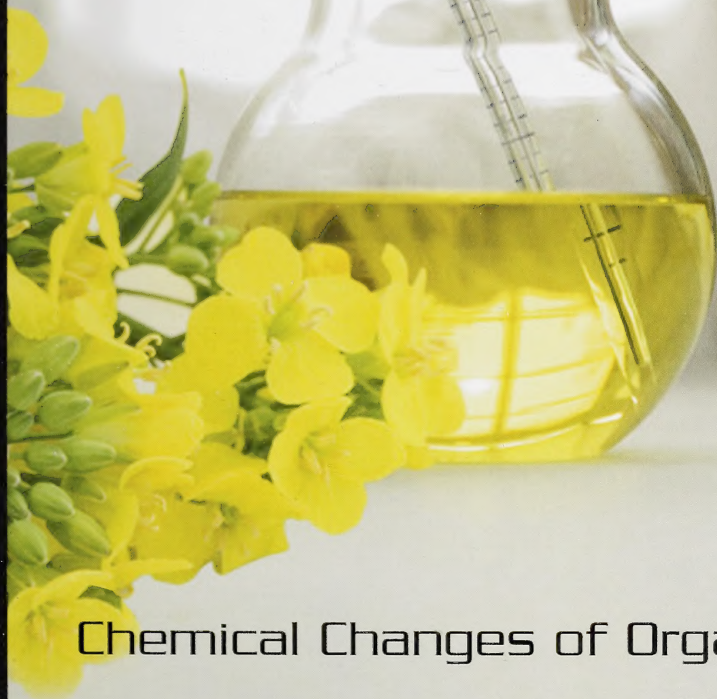




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Chemical Changes of Organic Compounds Unit C



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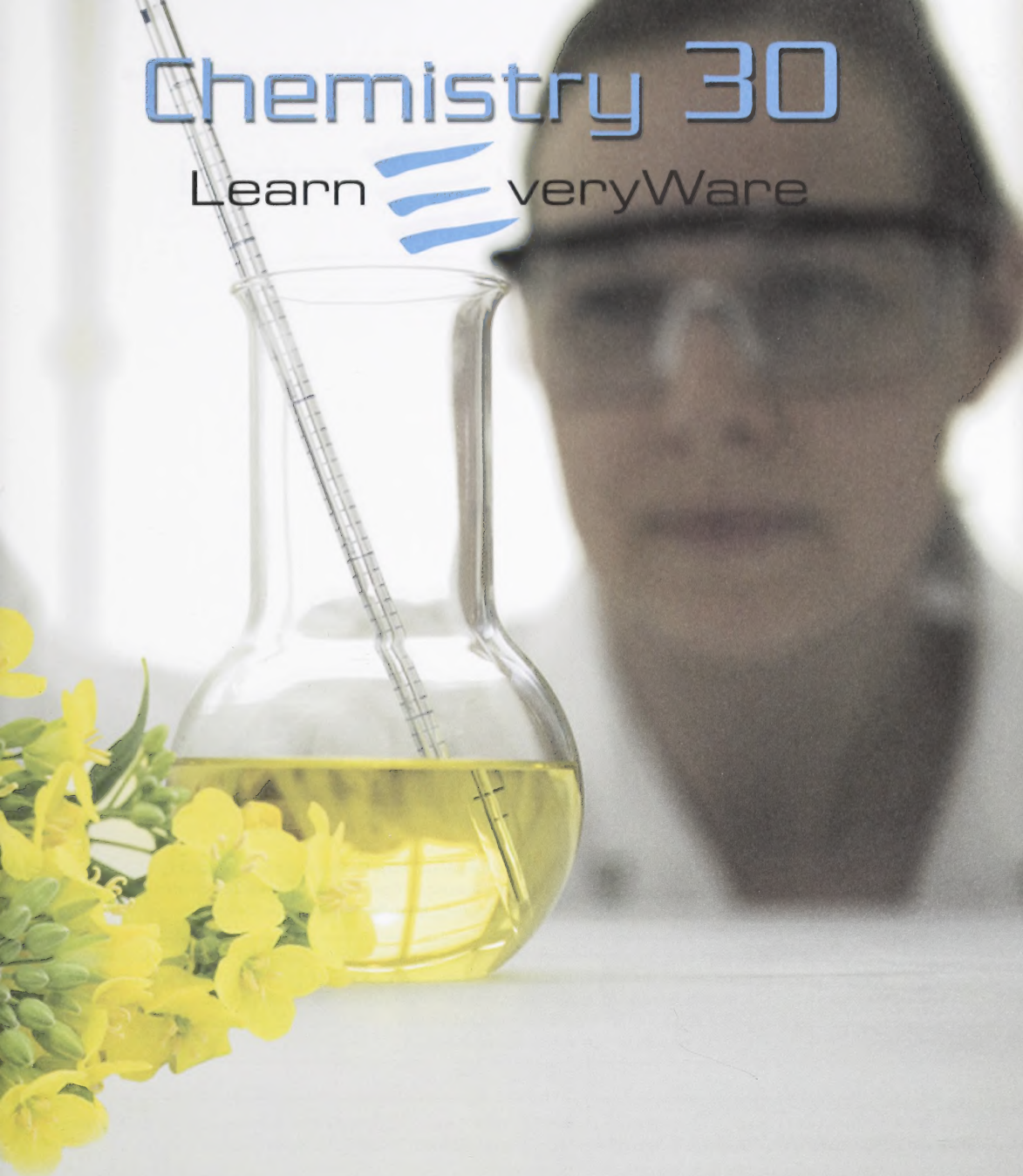
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Chemical Changes of Organic Compounds
Unit C

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Chemistry 30 Learn EveryWare
Unit C: Chemical Changes of Organic Compounds
Student Module Booklet
ISBN 978-0-7741-3180-3

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General Public	
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- Alberta Education, <http://www.education.gov.ab.ca>
- Learning Resources Centre, <http://www.lrc.education.gov.ab.ca>
- Tools4Teachers, <http://www.tools4teachers.ca>

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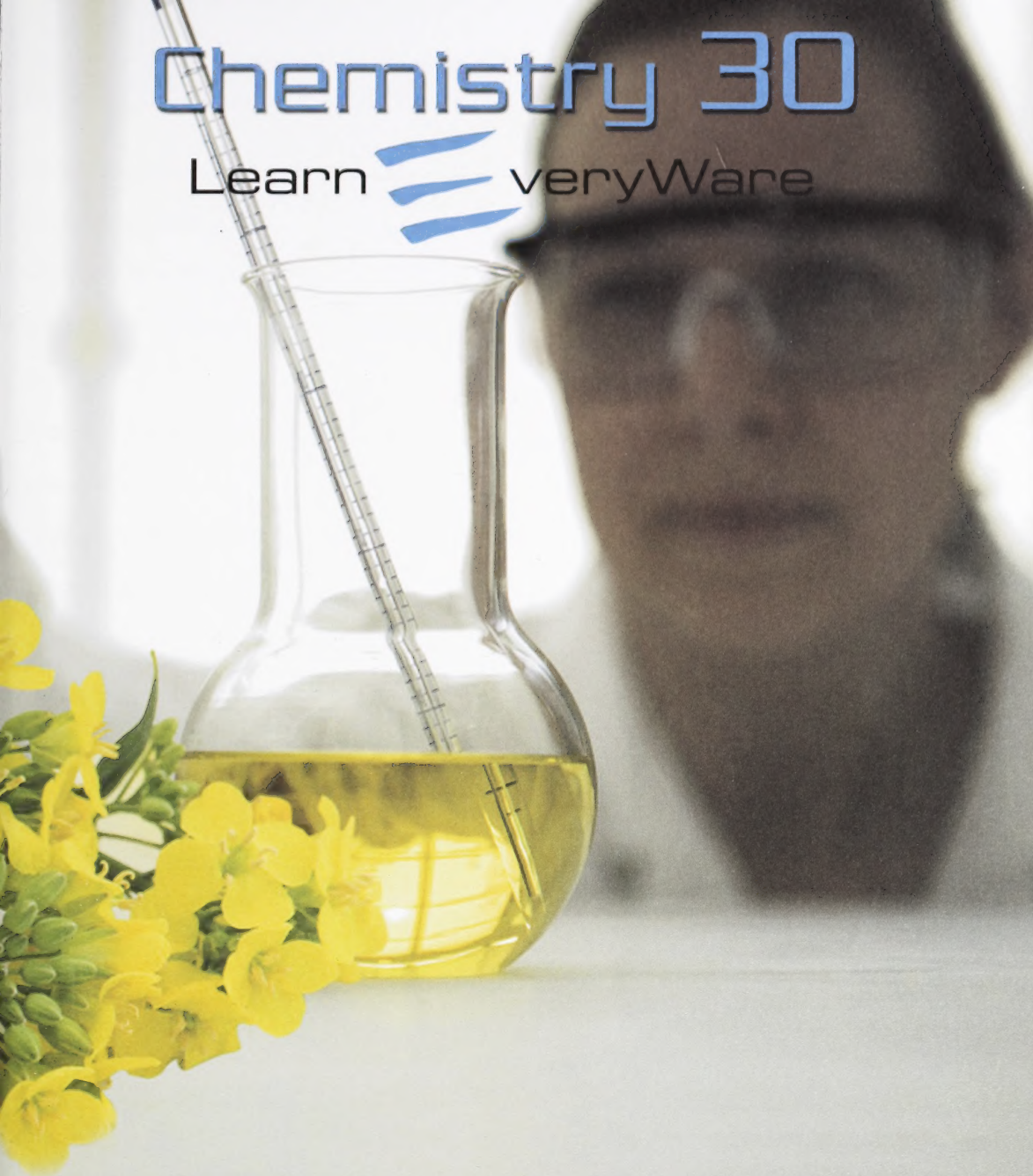
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Chemistry 30

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Hydrocarbons and the Petroleum Industry

Module 5



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This image displays a variety of personal care and grooming items. It includes two green hairbrushes, a green shampoo bottle, a blue conditioner bottle, a pink spray bottle, a blue lotion bottle, a silver curling iron, a silver straightener, a blue perfume bottle, a red lipstick tube, a blue deodorant can, a yellow-handled brush, a round open tin of cream, a green body lotion bottle, and a pink hairbrush. The items are arranged in a scattered pattern against a white background.

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The petroleum industry is considered a keystone industry in Alberta. It produces more than 70 000 products used by society on a daily basis, creates thousands of jobs, and, as you learned in Module 4, generates significant tax revenues for the province of Alberta. Without the petroleum industry in Alberta, Albertans' quality of life would drop significantly. In Module 5 you will learn about hydrocarbons, the basis of the petroleum industry.

The petrochemical industry is an important subset of the petroleum industry. In Module 6 you will learn how and what petrochemicals are produced and used in Alberta, and you will begin to assess the sustainability of this chemical industry. You will investigate the importance of the petrochemical industry and the impact the industry has on Alberta, Canada, and the world.

- identify and explain how organic compounds are a common form of matter
- describe chemical reactions of organic compounds

In the Unit C Assessment you will consider a chemical process used in the development of a common pharmaceutical compound, acetylsalicylic acid (ASA). You will consider this chemical process from different perspectives, which will require you to apply your knowledge of organic chemistry and chemical reactions.

Unit C Concept Organizer

Unit C—Chemical Changes of Organic Compounds

Unit C—Chemical Changes of Organic Compounds

Module 5—Hydrocarbons and the Petroleum Industry

Lesson 1—Fossil Fuels
Lesson 2—Alkanes
Lesson 3—Alkenes and Alkynes
Lesson 4—Aromatics
Lesson 5—Alberta's Oil Industry
Lesson 6—Environmental Impact of Fossil Fuels and Alberta's Oil Industry

Module 6—Petrochemicals

Lesson 1—Petrochemicals in Alberta
Lesson 2—Organic Halides
Lesson 3—Alcohols
Lesson 4—Carboxylic Acids and Esters
Lesson 5—Addition Polymers
Lesson 6—Condensation Polymers

Module Descriptions

Module 5—Hydrocarbons and the Petroleum Industry

The petroleum industry is considered a keystone industry in Alberta. It produces more than 70 000 products used by society on a daily basis, creates thousands of jobs, and, as you learned in Module 4, generates significant tax revenues for the province of Alberta. Without the petroleum industry in Alberta, Albertans' quality of life would drop significantly. In Module 5 you will learn about hydrocarbons, the basis of the petroleum industry.

You will consider the following module questions:

- What is petroleum?
- What does Alberta's petroleum industry do?
- Where do hydrocarbons come from?
- What are hydrocarbons and what makes them such an important class of compounds?
- What are some of the processes that occur within Alberta's petroleum industry?
- What impact does the hydrocarbon industry have on Alberta's economy and environment?

Module 6—Petrochemicals

The petrochemical industry is an important subset of the petroleum industry. In Module 6 you will learn how and what petrochemicals are produced and used in Alberta. You will also begin to assess the sustainability of this chemical industry. You will investigate the importance of the petrochemical industry and the impact the industry has on your community, Alberta, Canada, and the world.

You will consider the following module questions:

- What kinds of chemical reactions are used to manipulate hydrocarbons in order to produce petrochemicals?
- How has the chemical industry responded to concerns about the environment?
- What are some of the processes that occur within Alberta's petrochemical industry?

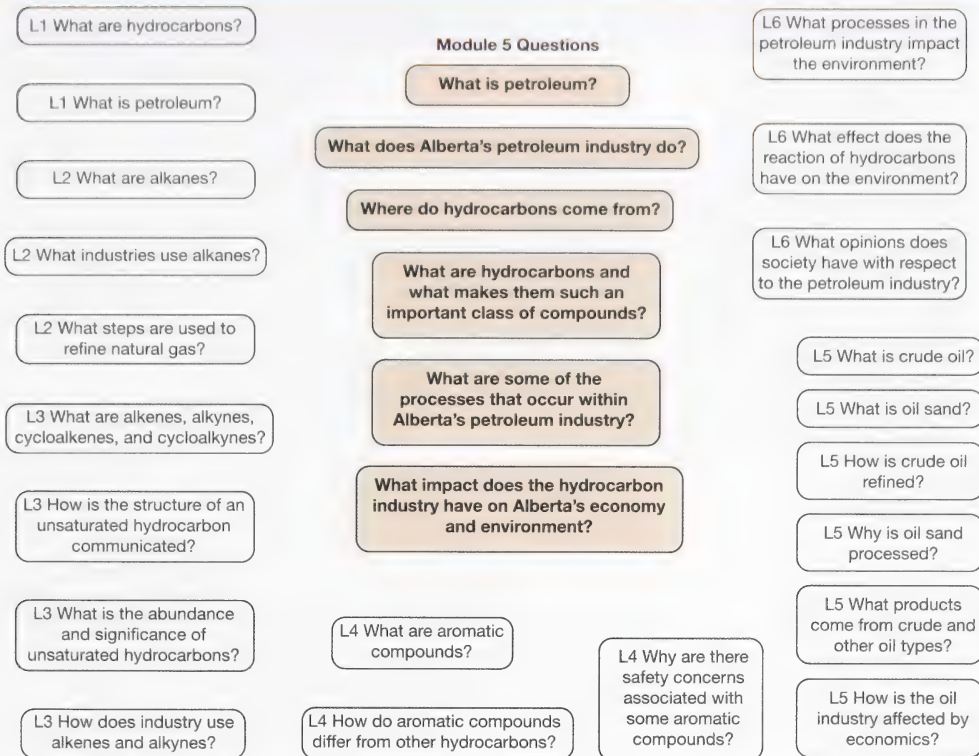
Using the Concept Organizer

Each module and lesson contains focusing questions intended to guide your study. Concept organizers are provided for each module. The Module 5 and Module 6 concepts organizers, which list the module and lesson questions, are provided at the end of this section.

As you work your way through each module, think about how the lesson questions relate to the module questions and to questions from other lessons. Use the concept organizers to build a concept map or a graphic organizer for each module. To do this, you might use software you already have on your computer, or you might do an Internet search for free software you can use. In your concept map or graphic organizer, record and demonstrate how the lesson and module concepts are connected and interdependent.

Sample concept maps are provided in the Module Summary for each module. Remember that the samples are just that—they show only one of many possible descriptions. However, if your completed concept map or graphic organizer differs significantly from the sample, you may wish to contact your teacher or to compare your map or organizer to those of your classmates. This will ensure that your interpretations of lesson materials and your descriptions are accurate.

Module 5 Concept Organizer



Module 6 Concept Organizer

L1 What are petrochemicals?

L1 What kinds of products result from Alberta's petrochemical industry?

L6 How do natural and synthetic polymers compare?

L2 What are organic halides?

What kinds of chemical reactions are used to manipulate hydrocarbons to produce petrochemicals?

L6 What are other reaction mechanisms by which polymers can be made?

L2 In what reactions are organic halides involved?

What are some of the processes that occur within Alberta's petrochemical industry?

L5 What is the process used to make plastic?

L3 What are alcohols?

How has the petroleum industry responded to concerns about the environment?

L3 Are alcohols being produced and used in a responsible way?

L5 What properties must molecules have if they are to be used in making plastic?

L4 what are carboxylic acids and esters?

L4 How are carboxylic acids and esters involved in the petrochemical industry?

Module 5—Hydrocarbons and the Petroleum Industry

Module Introduction

In Module 5 you will investigate the structure and properties of hydrocarbon molecules. You will learn about the sources of hydrocarbons, and how these natural resources are developed by society. You will learn about the industries that are involved in the extraction, refining, modification, and manipulation of hydrocarbon molecules. You will build on and apply what you learn in this module to your study of petrochemicals in Module 6.



© 2008 Jupiterimages Corporation

In Module 5 you will investigate the following questions:

- What is petroleum?
- What does Alberta's petroleum industry do?
- Where do hydrocarbons come from?
- What are hydrocarbons and what makes them such an important class of compounds?
- What are some of the processes that occur within Alberta's petroleum industry?
- What impact does the hydrocarbon industry have on Alberta's economy and environment?

Remember that each lesson will also be organized around questions intended to guide your study. As you proceed through Module 5, you may record answers to these questions and any interrelationships that exist between them in a concept map or graphic organizer. More information is available in the Unit C Concept Organizer. In the Module 5 Summary you will receive further information on how you can use your concept map or graphic organizer to review the concepts you studied in this module.



Big Picture

As a resident of Alberta you have probably seen many pumpjacks. You might have wondered what pumpjacks are doing in the middle of fields. A pumpjack is installed into an oil well (a hole drilled deep into the ground) to mechanically lift an oil and water mixture out of the ground.

Each stroke of the pumpjack can lift between five and 30 litres of the oil and water mixture. Once the mixture is brought to the surface, the process of refining the crude oil can begin.



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Crude oil is one type of fossil fuel. The number of pumpjacks you see in fields indicates that Alberta has a lot of crude oil. You may also have seen evidence of other types of fossil fuel resources being developed. For example, you may have seen evidence of coal mining and natural gas wells.

The abundance of fossil fuel resources in Alberta drives Alberta's economy and is at the core of many industries in Alberta. The recovery and refinement of fossil fuels makes Alberta a wealthy province.

As important as fossil fuels are to Alberta's economy, there have always been concerns about the impact the development of fossil fuel resources has on the environment. Does the extraction and refinement of fossil fuels cause irreparable damage to the environment?



Assessment in This Module

Each lesson contains a range of activities and assessment options. These include assignments, labs, and Self-Check, Try This, Discuss, Reflect and Connect, and Reflect on the Big Picture activities. Instructions will be provided for each of these activities so that you can appropriately focus your time and effort. Your teacher will tell you which assessment options to complete and which responses to submit for marks or feedback. Remember to save all of your work in your Chemistry 30 folder.

In the Module 5 Assessment you will prepare a list of hydrocarbons. You will identify the importance of each hydrocarbon from more than just a scientific perspective.

You may wish to look at the Module Assessment and the Unit Assessment before starting Lesson 1.

In This Module

Lesson 1—Fossil Fuels

Have you observed evidence of the hydrocarbon industry in your local area? In Lesson 1 you will begin to investigate the kinds of activities that are involved in the extraction and processing of hydrocarbons from petroleum.

You will investigate the following lesson questions:

- What are hydrocarbons?
- What is petroleum?

Lesson 2—Alkanes

Once petroleum is extracted, the refining process can begin. In Lesson 2 you will learn about different kinds of hydrocarbon molecules. You will specifically learn about alkanes, a type of hydrocarbon molecule that is present in, and must be separated from, natural gas. You will also consider the use of coalbed methane as an energy source.

You will investigate the following lesson questions:

- What are alkanes?
- What industries use alkanes?
- What steps are used to refine natural gas?

Lesson 3—Alkenes and Alkynes

There are hundreds of thousands of different hydrocarbon molecules. How do you communicate a particular type of hydrocarbon molecule? In Lesson 3 you will learn about the systematic naming process used to identify four more classes of hydrocarbon molecules.

You will investigate the following lesson questions:

- What are alkenes, alkynes, cycloalkenes, and cycloalkynes?
- How is the structure of an unsaturated hydrocarbon communicated?
- What is the abundance and significance of unsaturated hydrocarbons?
- How does industry use alkenes and alkynes?

Lesson 4—Aromatics

In Lesson 3 you learned that hydrocarbon molecules can exist in closed structures. One group of hydrocarbons has a unique closed structure, the aromatic ring. In Lesson 4 you will learn about aromatic compounds and how their properties make them a distinct group of hydrocarbons.

You will investigate the following lesson questions:

- What are aromatic compounds?
- How do aromatic compounds differ from other hydrocarbons?
- Why are there safety concerns associated with some aromatic compounds?

Lesson 5—Alberta's Oil Industry

There is more to Alberta's oil industry than pumpjacks. Alberta has heavy oil reserves and vast reserves of oil sand. In Lesson 5 you will investigate the different types of petroleum resources that are being developed in Alberta.

You will investigate the following lesson questions:

- What is crude oil?
- What is oil sand?
- How is crude oil refined?
- Why is oil sand processed?
- What products come from crude and other oil types?
- How is the oil industry affected by economics?

Lesson 6—Environmental Impact of Fossil Fuels and Alberta's Oil Industry

In previous science courses you were introduced to the concept of a greenhouse effect. The greenhouse effect identifies a central relationship between the combustion of hydrocarbons and the warming of Earth's atmosphere. In Lesson 6 you will review this evidence, and you will consider other local, provincial, national, and international impacts of Alberta's hydrocarbon and petroleum industries.

You will investigate the following lesson questions:

- What processes in the petroleum industry impact the environment?
- What effect does the reaction of hydrocarbons have on the environment?
- What opinions does society have with respect to the petroleum industry?

Module 5—Hydrocarbons and the Petroleum Industry

Lesson 1—Fossil Fuels



Get Focused



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Are there structures like the ones shown in this picture in your

petroleum: a mixture of hydrocarbons that is obtained from oil or natural gas

community? Evidence of Alberta's **petroleum** industry is part of the landscape in many parts of the province. Pipelines, flares, and refineries are obvious indications of the level of this industry's activity in Alberta.

You may have noticed vehicles that have the names of oil and gas companies on them or the names of companies that support the exploration and extraction of oil, natural gas, and oil sand. Those are more obvious examples of the activity of the petroleum industry. Are there other examples of this industry's activity that are less obvious but that still have an

impact on your community?

In Lesson 1 you will begin to explore the petroleum industry.

Consider the following questions as you complete Lesson 1:

- What are hydrocarbons?
- What is petroleum?



Module 5: Lesson 1 Assignment

In this lesson you will research and create a short write-up for a job in or related to the petroleum industry. You will be directed to go to the Assignment Booklet to complete the Module 5: Lesson 1 Assignment later in this lesson.

The other questions in this lesson are not marked by the teacher; however, you should still answer these questions. The Self-Check, Try This, and other types of questions are placed in this lesson to help you review important information and build key concepts that may be applied in future lessons. You should record the answers to all of the questions in the lesson and place those answers in your course folder.

After a discussion with your teacher, you must decide what to do with the questions that are not part of your assignment. For example, you may decide to submit the responses to Try This and other questions that are not marked to your teacher for informal assessment and feedback. Your answers are very important to your teacher. They provide your teacher with information about your learning, and they help your teacher identify where adjustments to your instruction may be necessary.



Explore



Try This

Examine the map shown in “Figure 2” on page 359 of the textbook. Locate approximately where you live and the type(s) of fossil fuels found in your area.

Use a camera to take a picture of something that demonstrates activity around the natural petroleum resource in your area. If you do not have a camera, sketch a drawing or otherwise obtain an image of the activity. Obtain enough information to write a caption describing your photograph. Your caption should include a brief description of the object photographed, the object’s location, and any other relevant information.

Save your photograph and caption in your course folder.



Post your photograph and caption to the discussion area for your class. Look at other students’ postings. Do you see any forms of activity that surprise you?

In your course folder, save a list of anything that surprises you or that you did not previously know about the petrochemical industry.



Read

Petroleum is a mixture of **hydrocarbons**. There are six main raw sources of hydrocarbons: natural gas, coalbed methane, crude oil, heavy oil, oil sands, and coal.

hydrocarbon: a compound containing only carbon and hydrogen atoms

Read pages 356–359 in the textbook to learn more about the natural sources of hydrocarbons.

From your reading you have learned that the petroleum industry involves locating, extracting, and refining natural resources. The petrochemical industry is also part of the petroleum industry. In the petrochemical industry, chemicals created from fossil fuels are used to make products such as antifreeze windshield fluid and plastics.

In TR 1 you took a photograph as evidence of a petroleum industry activity in your area. Can you identify what aspect of the petroleum industry your photograph represents? If so, add this information to the caption you saved in your course folder.



Self-Check

Complete “Case Study” questions 1–4 on page 360 and “Section 9.1” questions 1–8 on page 361 of the textbook.

Check your work with the answer in the appendix.



Reflect and Connect

As you are approaching the end of your high school education, you may have begun to consider your career options. Many businesses and occupations in Alberta have been able to grow due to involvement either directly in or supporting the petroleum industry. Are any of the career options you are considering related to the petroleum industry?



Module 5: Lesson 1 Assignment

Open the Assignment Booklet. Complete “Module 5: Lesson 1 Assignment.”



Reflect on the Big Picture

Oil sands development is a hot topic these days. Alberta’s largest oil sands deposit is located around Fort McMurray. The Fort McMurray deposit is estimated to have vast hydrocarbon reserves. Development of these oil sands requires a large financial investment.



Go to the course multimedia DVD, and view “The Alberta Oil Sands: A World of Opportunity—Part 1” and “The Alberta Oil Sands: A World of Opportunity—Part 2” to see how the Government of Alberta is promoting the potential of the oil sands and investment in developing this natural resource.



Lesson Summary

In Lesson 1 you considered the following questions:

- What are hydrocarbons?
- What is petroleum?

Alberta's petroleum industry locates, extracts, and refines natural gas, coalbed methane, crude oil, heavy oil, oil sand, and coal. In Lesson 1 you identified the type of molecules present in petroleum and some of petroleum's chemical characteristics. You began to explore how the petroleum industry impacts your community, and you looked at some of the career options available in the petroleum industry.

Lesson Glossary

hydrocarbon: a compound containing only carbon and hydrogen atoms

petroleum: a mixture of hydrocarbons that is obtained from oil or natural gas

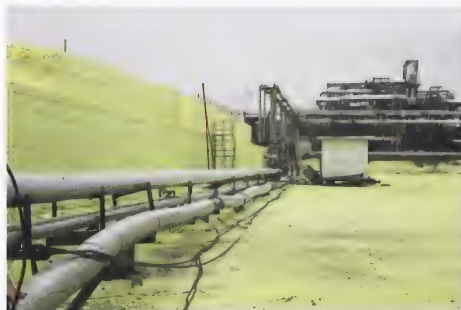
Module 5—Hydrocarbons and the Petroleum Industry

Lesson 2—Alkanes



Get Focused

Hydrocarbons are a unique collection of molecules. Natural gas is a rich source of hydrocarbon molecules. Refineries, like the ones pictured on page 363 of the textbook and in the photo here, separate components of natural gas. In Alberta there are over 750 plants that produce and refine natural gas.



Hydrogen sulfide is a component of some natural gas resources. Hydrogen sulfide, water, and carbon dioxide are common products of natural gas refining. The final product of hydrogen sulfide removal is elemental sulfur. Judging by the size of the sulfur block pictured here, a large quantity of natural gas and hydrocarbons were refined at this facility.

In Lesson 2 you will continue to learn about hydrocarbons, and you will learn how to distinguish and communicate the differences in the chemical structure of hydrocarbon molecules.

Consider the following questions as you complete Lesson 2:

- What are alkanes?
- What industries use alkanes?
- What steps are used to refine natural gas?



Module 5: Lesson 2 Assignment

In this lesson you will complete a case study on the extraction of coalbed methane. You will be directed to go to the Assignment Booklet to complete the Module 5: Lesson 2 Assignment later in this lesson.

You must decide what to do with the questions that are not marked by the teacher.

Remember that these questions provide you with the practice and feedback that you need to successfully complete this course. You should respond to all the questions and place those answers in your course folder.



Explore



Read

Read pages 362–363 in the textbook to learn more about natural gas, including its composition and refinement.



Self-Check

There are six main steps in the natural gas refining process:

1. Water and liquid hydrocarbons are removed from the gas.
2. Hydrogen sulfide gas is removed through a reaction with an amine.
3. Hydrogen sulfide gas reacts with oxygen to make sulphur dioxide.
4. The remaining hydrogen sulfide and sulphur dioxide are further recovered to make blocks of sulphur.
5. The remaining parts are cooled under high pressure to condense all components except methane.
6. The condensed liquid is distilled to further separate the components.

SC 1. Prepare a table showing which of these steps involve chemical reactions and which involve physical changes.

Check your work with the answer in the appendix.



Read

“Table 1” on page 363 of the textbook lists six hydrocarbon components of natural gas. The main components are methane, propane, ethane, and pentane. What is similar about these molecules?

Read pages 366–367 in the textbook.

The components of natural gas all end in “ane” and are considered **alkanes**. As hydrocarbons, alkanes are composed of only hydrogen and carbon.

alkanes: a class of hydrocarbons that contain only single bonds

Methane, ethane, propane, and butane represent the simpler alkane molecules. Regardless of the number of carbon atoms, an alkane will always have single bonds between all carbon atoms. The remaining bonds that carbon atoms can make are to hydrogen atoms.

You will recall from your work in Chemistry 20 that carbon atoms have four bonds to other atoms. For alkanes, each carbon will be chemically bonded to four other atoms, either carbon or hydrogen.



Try This

Molecular Models of C_5H_{12}

How many different forms can a molecule with the formula C_5H_{12} have? Use materials you find at home or at school to construct a molecular model of each of the different forms you identify. Recall the following information when constructing your representations of hydrocarbons:

1. Carbon atoms can bond with up to four other atoms.
2. Hydrogen atoms can only bond with one other atom.
3. In alkanes, only one bond exists between two adjacent carbon atoms.
4. The general chemical formula for an alkane is C_nH_{2n+2} .

TR 1. Use a digital camera to take a picture of each of the models you constructed. If you do not have a digital camera, sketch your drawings digitally (using a program on your computer) or by hand.

TR 2. Summarize your work in a table. The table should have a column for each of the molecular models you constructed and a row for the pictures you took. Paste your pictures or sketches in your table. Later in this lesson, you will add rows to the table as you re-examine the molecules you constructed.

TR 3. Explain the principle underlying information points 1 and 2 above.

Save your work in your course folder.



Read

Methane, ethane, propane, and butane represent the simpler, linear alkane molecules. In TR 1–3 you probably noticed that the molecules you constructed had either linear appearances—all carbons connected to form a continuous chain, or branched appearances—one or more carbon atoms bonded to only a single carbon along the continuous chain.

Read pages 367–368 in the textbook to learn more about branched hydrocarbons. Complete “Sample problem 9.1” and “Communication example 1” on pages 368–369 of the textbook. In Module 6 you will learn that hydrocarbons with branches can be manufactured.

**Self-Check**

SC 2. Retrieve a copy of the table you started in TR 2. Add a row with the heading “Systematic Name.” Use the information listed on page 368 of the textbook to write the name for each of the molecules represented in your table. Save a copy of your table in your course folder.

Check your work with the answer in the appendix.

The different forms of C_5H_{12} you constructed and named in TR 1–3 and SC 2 are examples of **structural isomers**.

The ability of a carbon atom to have up to four bonds creates the possibility of branching along the length of a hydrocarbon molecule. An **alkyl branch** is not part of the main chain and

contains only carbon and hydrogen. Even though they have the same molecular formula, each structure is considered a different entity. Not only do the isomers have different names, but often they have differences in their properties, which can allow them to have different uses.

structural isomers: compounds that share the same chemical formula but have different chemical structures

alkyl branch: a group of carbon and hydrogen atoms joined by single bonds

The group is not part of the main structure of a hydrocarbon.

**Read**

Read “Drawing Branched Alkane Structural Formulas” and complete “Sample problem 9.2” and “Communication example 2” on pages 369–370 of the textbook.

**Self-Check**

SC 3. Retrieve a copy of the table you last updated in SC 2. Add one row with the heading “Structural Formula,” and one row with the heading “Condensed Structural Formula.” Complete the information for the new rows of your table for each of the three isomers of pentane.

SC 4. Complete “Practice” questions 7–11 on pages 370–371 in the textbook.

Check your work with the answer in the appendix.



Read

Some alkanes form into cyclical structures called **cycloalkanes**. In these structures the carbon chain forms a circle. For more information about cycloalkanes, including how to name and draw structures for these molecules, read “Cycloalkanes” and complete “Communication example 3” and “Communication example 4” on pages 371–372 in the textbook.

cycloalkanes: a cyclic (carbon chain forms a circle) hydrocarbon in which all of the bonds between carbon atoms are single bonds



Self-Check

SC 5. Complete “Section 9.2” questions 1–10 on pages 372–373 of the textbook.

Check your work with the answer in the appendix.



Module 5: Lesson 2 Assignment

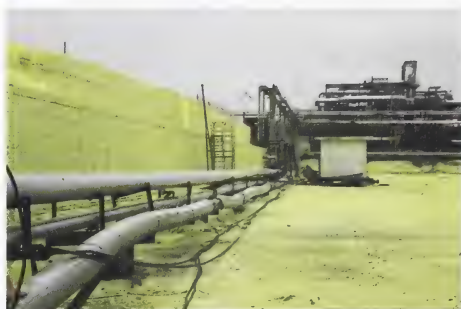
Open the Assignment Booklet. Complete “Module 5: Lesson 2 Assignment.”



Reflect on the Big Picture

At the beginning of this lesson you saw a picture of a sulfur block, a by-product of the refining of sour natural gas. Sulfur blocks, like the one pictured, can be well over the size of a city block. Seeing a structure like that might make you think about the environmental impact of extracting, refining, and even using hydrocarbons.

Can you identify evidence of an adverse environmental impact caused by the petroleum industry in your local area? Capture any evidence you see using your camera or make a list of your observations. Save your evidence in your course folder.





Lesson Summary

In Lesson 2 you considered the following questions:

- What are alkanes?
- What industries use alkanes?
- What steps are used to refine natural gas?

You identified that natural gas is a source of alkanes, and that alkanes are a diverse group of hydrocarbon molecules that can have a variety of structural forms. You learned to identify the key components of alkanes, to draw their chemical structures, and to write the systematic names for an alkane and its isomers. You also began to consider the petroleum industry from a variety of perspectives, and you collected evidence of the petroleum industry's impact on your local area.

Lesson Glossary

alkanes: a class of hydrocarbons that contain only single bonds

alkyl branch: a group of carbon and hydrogen atoms joined by single bonds

The group is not part of the main structure of a hydrocarbon.

cycloalkanes: a cyclic (carbon chain forms a circle) hydrocarbon in which all of the bonds between carbon atoms are single bonds

structural isomers: compounds that share the same chemical formula but have different chemical structures

Module 5—Hydrocarbons and the Petroleum Industry

Lesson 3—Alkenes and Alkynes



Get Focused

How careful are you about storing fruits and vegetables? Did you know that the ripening of fruits and vegetables can be influenced by other produce or even by the container in which the produce is stored? It might surprise you to know that a simple but important hydrocarbon molecule influences the ripening process.

Fruits and vegetables release ethylene, which acts as a hormone in fruits and vegetables and influences their ripening and aging. Ethylene is also called ethene and has the chemical formula C_2H_4 .



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You may notice that the name and chemical formula of ethene is different from the alkanes you studied in the previous lesson. In Lesson 1 you learned that the rules used to name hydrocarbons allowed for communicating the structure of the molecule. How might ethene be different from ethane? What aspects of these two molecules might be similar?

In Lesson 3 you will focus on other classes of hydrocarbons—alkenes, alkynes, cycloalkanes, and cycloalkenes.

Consider the following questions as you complete Lesson 3:

- What are alkenes, alkynes, cycloalkenes, and cycloalkynes?
- How is the structure of an unsaturated hydrocarbon communicated?
- What is the abundance and significance of unsaturated hydrocarbons?
- How does industry use alkenes and alkynes?



Module 5: Lesson 3 Assignment

The Lesson 3 assignment will assess your ability to name and write structural formulas for the types of hydrocarbons you studied in Lessons 2 and 3. You will be directed to go to the Assignment Booklet to complete the Module 5: Lesson 3 Assignment later in this lesson.

You must decide what to do with the questions that are not marked by the teacher.

Remember that these questions provide you with the practice and feedback that you need to successfully complete this course. You should respond to all the questions and place those answers in your course folder.



Explore



Try This

Constructing Ethene

TR 1. Ethene, the hydrocarbon plant hormone, has the chemical formula C_2H_4 . Use materials in your home or classroom to build a model of the ethene molecule. Remember that each carbon atom must bond four times in order to achieve stability.

TR 2. Write the chemical structure and the condensed chemical structure for the molecule you constructed.

Save the structure you built—you will refer back to it later in this lesson. You may wish to check your work with your teacher.



Read

Read pages 374–376 in the textbook to learn more about the structure of alkenes and alkynes and how to name and draw structures for these compounds. Complete “Communication example 1” on page 375 and “Communication example” 2 on page 376 of the textbook.



Self-Check

SC 1. Use materials in your home or school to construct models or draw chemical structures for four isomers of C_4H_8 . Complete a table like the one provided here to summarize information about the isomers of C_4H_8 .

When building your models, remember that each carbon atom must bond four times in order to achieve stability; each hydrogen can only bond once.

	Isomer of C ₄ H ₈			
Structural Formula				
Condensed Structural Formula				
Line Diagram				
Name				
Type of Hydrocarbon				

Check your work with the answer in the appendix.



Read

Read the section “Cycloalkenes and Cycloalkynes” on pages 376–377 in the textbook.



Self-Check

SC 2. Complete “Practice” questions 1–5 and 7 on page 377 in the textbook.

Check your work with the answer in the appendix.



Read

Alkenes and other unsaturated hydrocarbons can exist naturally but are usually found in very low quantities. As a result, they are more often made from other hydrocarbons. Because it is used to produce a variety of products, including plastics, ethene is one of the most desirable hydrocarbons.

Ethane is produced by a process called **cracking**. Read more about ethane cracking on pages 378–379 in the textbook.

Compare the chemical reactions for cracking shown on page 379 with the hydrogenation reaction shown on page 374 in the textbook. Can you identify any relationship, similarities, and differences between the two reaction types?

cracking: a process in which larger hydrocarbon molecules are converted into smaller hydrocarbon molecules



Module 5: Lesson 3 Assignment

Open the Assignment Booklet. Complete the “Module 5: Lesson 3 Assignment.”



Reflect and Connect

The fruit production industry has taken advantage of the ethene that is naturally produced by plants to better prepare fruits and vegetables for shipment, storage, and sale. By controlling the concentration of ethene around produce, the ripening process can be delayed or stimulated as required.

Inspection of produce prior to shipment is very important, because damaged fruits and vegetables produce more ethene. If damaged produce is not removed, it may be a case of one bad apple spoiling the whole bunch!

To promote ripening at home, some people place ethene-producing fruits, like bananas, peaches, pears, and nectarines, in bags with produce that is more sensitive to ethene, such as broccoli, leafy green vegetables, tomatoes, and mangos.



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Reflect on the Big Picture

In this lesson you learned that cracking reactions are used to dehydrogenate ethane extracted from natural gas. You also learned that ethene can also be produced from larger hydrocarbons extracted from other petroleum sources. In Module 6 you will learn more about reactions that use ethene, including the process used to convert ethene into plastic.

Look around the room in which you are sitting. Do you see many products made from plastic? These products are evidence of the importance of ethene and of this class of hydrocarbons.





Lesson Summary

In Lesson 3 you considered the following questions:

- What are alkenes, alkynes, cycloalkenes, and cycloalkynes?
- How is the structure of an unsaturated hydrocarbon communicated?
- What is the abundance and significance of unsaturated hydrocarbons?
- How does industry use alkenes and alkynes?

Alkenes, alkynes, cycloalkenes, and cycloalkynes are classes of hydrocarbon molecules that possess double or triple bonds. Molecules of these classes exhibit properties that make them highly useful in industrial processes.

In this lesson you were introduced to the procedures used to name and write the structures for these compounds. You also learned about some chemical reaction types that are used in their production and use. In Module 6 you will learn more about the reactivity and chemical processes involving these unsaturated hydrocarbons.

Lesson Glossary

cracking: a process in which larger hydrocarbon molecules are converted into smaller hydrocarbon molecules

Module 5—Hydrocarbons and The Petroleum Industry

Lesson 4—Aromatics



Get Focused

What happens when a gasoline station closes? Have you seen what it takes to reclaim the area? It's pretty hard to miss the excavation of the underground fuel tank, but many of us don't notice the removal of the soil—lots of soil!

Gasoline is a mixture of many hydrocarbons. In the past, benzene was added to fuel to improve fuel's performance. You might have heard of benzene—researchers suspect it causes cancer.

Benzene belongs to a class of hydrocarbons, the aromatic compounds, which occur naturally but have very unique chemical properties. How do the chemical properties of benzene relate to the clean-up of land at abandoned gas stations? In Lesson 4 you will begin to learn about benzene and aromatic compounds.

Consider the following questions as you complete Lesson 4:

- What are aromatic compounds?
- How do aromatic compounds differ from other hydrocarbons?
- Why are there safety concerns associated with some aromatic compounds?



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Module 5: Lesson 4 Assignment

There is no assignment for this lesson. However, you will be asked to submit samples of your work to your teacher where instructed.

You must decide what to do with the questions that are not marked by the teacher.

Remember that these questions provide you with the practice and feedback that you need to successfully complete this course. You should respond to all the questions and place those answers in your course folder.



Explore



Read

Aromatics include benzene and all compounds that contain a benzene-like structure. The chemical formula for benzene is C_6H_6 but the structural diagram is more difficult to pinpoint. The structure of benzene is unique to this class of hydrocarbons. This is a unique class of compounds because of its combination of physical and chemical properties.

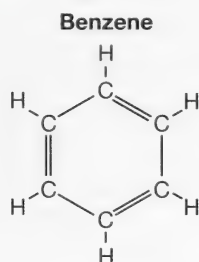
aromatics: a class of hydrocarbons in which all hydrocarbons contain benzene or a benzene-like ring

Read pages 381–382 in the textbook to learn more about the evidence that led to the development of a chemical structure for benzene.



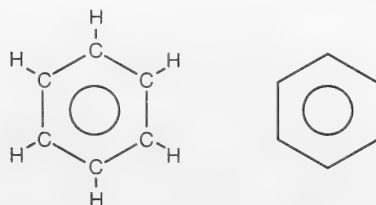
Try This

Consider this early model for the structure of benzene.



Identify one piece of evidence listed on page 381 that supports using this chemical structure as a representation for benzene and one piece of evidence that suggests this is not an appropriate representation for this molecule. Share your evidence with your teacher.

Consider the following two illustrations:



In both diagrams, the inner circle illustrates that there are not three specific double bond locations; rather, there is a way for all six carbons in the ring to bond to the remaining electrons.



Read

Read the section “Naming Aromatics” on pages 382–383 in the textbook. Complete “Communication example” and “Sample problem 9.3” on page 383.



For extra reinforcement, go to the course multimedia DVD, and listen to “Communication example audio description.”

Use these strategies when naming aromatics:

1. If there is an alkyl branch attached to a benzene, it is called an alkylbenzene.
2. If you have more than one alkyl branch attached to a benzene, always number the benzene ring so that the numbers are the lowest possible (you will always have a branch numbered one).
3. If there is a benzene ring attached to a larger molecule, the benzene is considered the branch and is called a phenyl branch.



Self-Check

Complete “Section 9.4” questions 1–10 on page 385 of the textbook.

Check your work with the answer in the appendix.



Reflect and Connect

Soil contaminated with hydrocarbons can be treated using **bioremediation**. Bacteria that commonly live in the soil use many hydrocarbons as a food source. These bacteria remove hydrocarbons from the soil by eating them.

bioremediation: a process that uses natural mechanisms, including bacteria and fungi, to remove toxic materials from soil or water

Because of the chemical structure of the benzene ring, soil contaminated with benzene compounds is much more difficult to bioremediate. The unique bonding relationship in a benzene ring makes benzene a highly stable chemical structure. Soil and other material contaminated with benzene



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and other harmful aromatic compounds are often treated using special waste treatment processes.



Reflect on the Big Picture

Benzene is currently a restricted chemical substance. Benzene and other aromatic compounds are found in crude oil and natural gas and can be separated during refining. Despite its link to cancer, benzene is used in many chemical processes.

Prepare a list of products that are produced using benzene. Research what alternatives exist to the use of benzene.

Save a copy of your list in your course folder—you might wish to refer to this list in Module 6.



Lesson Summary

In Lesson 4 you considered the following questions:

- What are aromatic compounds?
- How do aromatic compounds differ from other hydrocarbons?
- Why are there safety concerns associated with some aromatic compounds?

Benzene and other aromatic compounds are naturally occurring compounds that possess a similar chemical structure, the benzene ring. As you have learned in this lesson, the benzene ring is a unique chemical structure that gives this class of compounds unique chemical properties.

There are significant health concerns associated with some aromatic compounds, some of which are restricted or have to be used with appropriate caution. Some common substances, such as Aspirin (a pain reliever) and vanillin (a flavouring agent), are aromatic compounds.

Lesson Glossary

aromatics: a class of hydrocarbons in which all hydrocarbons contain benzene or a benzene-like ring

bioremediation: a process that uses natural mechanisms, including bacteria and fungi, to remove toxic materials from soil or water

Module 5—Hydrocarbons and the Petroleum Industry

Lesson 5—Alberta's Oil Industry



Get Focused

So far in Module 5 you have learned about hydrocarbon compounds present in natural gas. Natural gas is only one of the natural sources of hydrocarbons in Alberta. As you can see in “Figure 2” on page 359 in the textbook, Alberta is also rich in hydrocarbons from oil—heavy oil, conventional crude oil, and oil sand.

Earlier in this module you were asked to look for evidence of activity in the petroleum industry in your local area. Was the activity you photographed related to natural gas, oil, or oil sand production?

In this lesson you will investigate the different types of petroleum resources that are being developed in Alberta.

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Consider the following questions as you complete Lesson 5:

- What is crude oil?
- What is oil sand?
- How is crude oil refined?
- Why is oil sand processed?
- What products come from crude and other oil types?
- How is the oil industry affected by economics?



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Module 5: Lesson 5 Assignment

You will be directed to go to the Assignment Booklet to complete the Module 5: Lesson 5 Assignment later in this lesson.

You must decide what to do with the questions that are not marked by the teacher.

Remember that these questions provide you with the practice and feedback that you need to successfully complete this course. You should

respond to all the questions and place those answers in your course folder.



Explore

Crude oil is a complex mixture of hydrocarbons. There are different types of crude oil. Read pages 386–387 in the textbook to learn more about the different types of crude oil, the property that determines the grade of crude oil, and the refining process.



Try This

Refining and other processes, like dewaxing, make use of the different boiling points of molecules within oil.



Go to the course multimedia DVD, and view the presentation “Fractional Distillation” to test your understanding of the principles and processes involved in oil refining. As you move your mouse over the possible answers in each question, a pop-up window will appear allowing you to self-score and to see where you chose incorrectly.

Only complete steps 1–10 at this time. You will complete the other steps later in this lesson.



Self-Check

SC 1. Complete “Practice” questions 1–6 on page 388 of the textbook.

Check your work with the answer in the appendix.



Read

Earlier in this module you learned that cracking is the process by which larger hydrocarbons are broken into smaller hydrocarbons. Cracking is one of the main processes used to modify molecules in crude oil into more desirable forms.

As you learned in the previous section, 95% of crude oil is used to produce fuels for heating or transportation. These fuels are a mixture of many hydrocarbons ranging in size from five to 12 carbons each. Read pages 389–391 in the textbook to learn more about the chemical processes and different types of cracking involved in refining oil.



Try This



Go to the course multimedia DVD, and open the presentation “Fractional Distillation” again. Use steps 11–15 to test your understanding of chemical processes in cracking and reforming, and of alkylation used in refining oils. Select the “i” shown on each page to view simulations of the processes described.



Self-Check

SC 2. Complete “Practice” questions 8–15 on pages 391–392 of the textbook.

Check your work with the answer in the appendix.



Read

Oil sand is a natural resource that is receiving a great deal of attention. Read page 395 in the textbook to learn more about oil sand and the extraction of the hydrocarbons, called bitumen, from oil sand.



Module 5: Lesson 5 Lab—Factors Influencing the Extraction of Bitumen from Oil Sand

Background

In your reading you learned that the inventor of a process used to extract bitumen from oil sand, Karl Clark, used carefully constructed experimentation to develop his process. Experiments to improve the recovery of bitumen from oil sand are still being carried out.

Purpose

To test the effect of variables used in the extraction of bitumen from oil sand. This investigation considers the following four variables and effect hypotheses:
extraction of bitumen from

- temperature: The amount of bitumen extracted from oil sand increases as the temperature increases.
- pH: The amount of bitumen extracted from oil sand increases as the pH increases.
- air: If air is bubbled into a bitumen mixture and the air bubbles are captured within the bitumen, then more bitumen floats to the top as froth.
- calcium ion concentration: Increasing the calcium ion concentration increases the quantity of bitumen froth but decreases the quality (purity) of the froth.



Go to the course multimedia DVD, and view the virtual investigation “Factors Influencing the Extraction of Bitumen from Oil Sand.” Contact your teacher for instructions about which parts of the virtual investigation to view and how to proceed with your analysis. Remember to record data and observations as you view the presentation.



Try This

TR 1. Identify the best conditions for the extraction of bitumen from oil sand. Explain how the results from the investigation you viewed support your conclusion.

TR 2. Explain how the results of the experiments in the investigation you viewed could be useful for developing technology that improves bitumen extraction.

TR 3. Can you identify any limitations to the conclusions you could draw from these experiments? How could these limitations be addressed?

Save your responses in your course folder, and submit a copy to your teacher.



Read

Oil sand is a mixture of hydrocarbons with a different chemical composition than crude oil. Because of oil sand's special composition, it must be refined differently than other sources of hydrocarbons, such as crude oil and natural gas.

Read page 396 of the textbook to learn more about how oil sand is refined and about how the hydrocarbons in bitumen undergo so many changes in the refining process that the end result is termed "synthetic crude oil."



Self-Check

Bitumen extracted from oil sand is a mixture containing a large proportion of aromatic hydrocarbons, whereas crude oils contain a larger proportion of aliphatic hydrocarbons. Both bitumen and crude oil are used to produce naphtha, a mixture of hydrocarbons composed of between five to 12 carbons.

SC 3. Draw chemical structures and provide names for three molecules that could be found in the naphtha fractions from the refining of bitumen and crude oil.

Check your work with the answer in the appendix.



Reflect on the Big Picture

Crude oil refining is a billion-dollar industry. As you have learned in this lesson, Alberta is a major producer of crude oil and synthetic crude oil. However, only a small percentage of this oil is refined in Alberta. It is cheaper to transport crude through pipelines to other major centres for refining than it is to refine the oil in Alberta. The refined oil can then be shipped shorter distances to users.



Go to the course multimedia DVD, and view "Pipeline Map of North America." Can you identify the markets for Alberta oil using the map?



Discuss

What are the responsibilities and consequences of being a crude oil producer and exporter? Is it appropriate to export oil? These are hot topics among Albertans and others. Many people believe that the synthetic crude oil sold by Alberta is “dirty oil” because of the environmental damage caused by extracting and refining bitumen.

Write a couple of paragraphs to share your opinion on whether Alberta should extract and refine crude oil. Post your response in the discussion area for your class and read the opinions of at least two other students.

Save your work in your course folder.



Module 5: Lesson 5 Assignment

Open the Assignment Booklet. Complete “Module 5: Lesson 5 Assignment.”



Lesson Summary

In Lesson 5 you considered the following questions:

- What is crude oil?
- What is oil sand?
- How is crude oil refined?
- Why is oil sand processed?
- What products come from crude and other oil types?
- How is the oil industry affected by economics?

You learned about conventional and synthetic crude oil and its sources, and you learned about the chemical and physical processes used to refine oil.

The crude oil industry produces gasoline, diesel, liquid petroleum gases, kerosene, waxes, tars, lubricating oils, and asphalt. As you will see in Module 6, other industries use different fractions from crude oil to create a wide range of products from plastics to cosmetics.

Module 5—Hydrocarbons and the Petroleum Industry

Lesson 6—Environmental Impact of Fossil Fuels and Alberta's Oil Industry

Get Focused



Far left: © JohnnyZ/shutterstock; balance: © 2008 Jupiterimages Corporation

Earlier in this module you collected photographic evidence of the petroleum industry's activity in your local area. You may also have taken pictures of the industry's effect on your community. Even if you did not take these photographs, you can probably list many examples of the industry's impact.

In this lesson you will expand your consideration of the petroleum industry's impact. You will use the evidence you collected, including your photographs and lists, to consider the impact of hydrocarbons from fossil fuels from a local, provincial, national, and international level. You will also research current trends in, and concerns regarding, the petroleum industry and some possible directions for its future.

Consider the following questions as you complete Lesson 6:

- What processes in the petroleum industry impact the environment?
- What effect does the reaction of hydrocarbons have on the environment?
- What opinions does society have with respect to the petroleum industry?

Module 5: Lesson 6 Assignment

You will be directed to go to the Assignment Booklet to complete the Module 5: Lesson 6 Assignment later in this lesson.

In this lesson you will also consider what you have learned about the petroleum industry, and you will identify questions about the future of this industry you feel need to be considered.

You must decide what to do with the questions that are not marked by the teacher.

Remember that these questions provide you with the practice and feedback that you need to successfully complete this course. You should respond to all the questions and place those answers in your course folder.



Explore



Read

The petroleum industry supplies fuel for automobiles. As a result, the petroleum and automobile industries are linked. One of the most common combustion reactions that occurs around you happens inside a car engine. From previous science courses you know there are products of combustion reactions. You may recall that some of these products can have global effects.



© Stephen Finn/shutterstock

Cars are often lined up at drive-thrus. Their engines are running, but they aren't going anywhere. Signs like the one shown in the photograph indicate there is concern about idling. Why the concern?

You may remember that a combustion reaction is the rapid reaction of a chemical with oxygen to produce oxides and heat. Read pages 398–400 in the textbook to learn more about combustion reactions and the concerns about tailpipe emissions and other exhaust.



Self-Check

SC 1. Write two balanced equations: one for the complete and one for the incomplete combustion of pentane. Compare the oxygen needed in each equation.

Check your work with the answer in the appendix.

Other Problems with Combustion Reactions

From your reading you know that the quantity of oxygen available to a hydrocarbon is important in ensuring complete combustion. But is ensuring complete combustion the answer to environmental concerns? In Chemistry 20 you learned about carbon dioxide, its action as a greenhouse gas, and how this has contributed to global climate change.

The quantity of uncombusted hydrocarbons present in automobile exhaust is another reason vehicle idling is a problem. These compounds can range from components initially in the fuel that do not react with oxygen at all, to new hydrocarbons produced as side products. Some of these hydrocarbons are the same compounds that are present in tobacco and other sources of smoke. You may know from health warnings that some of these compounds can be carcinogenic.



Self-Check

SC 2. Use the Internet to compile two lists of hydrocarbons: one for those present in car exhaust, and one for those present in diesel exhaust. Comment on the composition of each list. Can you identify any similarities between the substances appearing in each list?

Check your work with the answer in the appendix.



Read

Combustion processes using fossil fuels have other unwanted side products. Nitrogen monoxide, NO(g) , is a by-product of combustion reactions that occur at high temperatures, such as the temperature in an engine or furnace. Nitrogen monoxide and nitrogen dioxide are produced when NO reacts with oxygen in the atmosphere. These two compounds contribute to the production of acid deposition.

A gasoline component that contributes to the formation of acids is sulfur, often present within organic compounds in fuel. As you saw earlier, sulfur can be removed from natural gas. Efforts are underway to improve sulfur removal from other petroleum sources, including crude oil and natural gas.

Read page 393 in the textbook to learn more about the process used to remove sulfur from gasoline.



Self-Check

SC 3. Identify a possible negative side effect of improved sulfur removal practices during the refining of gasoline.

Check your work with the answer in the appendix.



Reflect on the Big Picture

Throughout your study in this module you have collected evidence of the petroleum industry's activity in your local area. You may have collected photographs, newspaper articles, or lists of events you have observed.

Go through the evidence you collected. Identify and consider some of the issues with which the evidence is connected. Use the steps below to guide your investigation.

Purpose

To consider the impact of the petroleum industry at local, provincial, and international levels.

Procedure

Step 1: Review the pieces of evidence you collected in this module. Prepare a list that identifies characteristics of the industry. For each characteristic, identify the perspectives represented. See page 45 of the textbook if you need help identifying perspectives.

For example, you may have a photograph of an equipment yard for an oilfield company. You might list a technological perspective—the machinery used to extract oil that is used to make gasoline, and an economic perspective—the company provides jobs for the local economy and taxes that support the community’s growth and other programs.

Step 2: Consider the information and perspectives from the list you prepared in Step 1. Identify one pressing issue that emerges or jumps out from your list. Describe how this issue relates to the petroleum industry.

Step 3: Can the pressing issue you identified be rephrased as a research question? For example, if your issue involved a concern about soil contamination at oil well sites, a possible research question might be, “Are there guidelines for reclaiming soil at oil well sites?”

Step 4: Type your research question into an Internet search engine. Save a copy of the search results.

Step 5: Comment on the first 15 search results. Is this an emotional issue, an issue of much debate, a focus of research, or a target for development of government policy?

Step 6: Predict how this issue will be resolved in the future. Support your prediction using evidence from your research or from other sources.

Save your work in your course folder. Contact your teacher to find out which parts of your work you should submit.



Module 5: Lesson 6 Assignment

Open the Assignment Booklet. Complete “Module 5: Lesson 6 Assignment.”



Lesson Summary

In Lesson 6 you considered the following questions:

- What processes in the petroleum industry impact the environment?
- What effect does the reaction of hydrocarbons have on the environment?
- What opinions does society have with respect to the petroleum industry?

The petroleum industry relies on many complex processes. The processes are not all chemical—the industry is also shaped by political, economic, technological, ecological, and societal issues and processes. The petroleum industry's future will be determined by considering and balancing the needs of all from a variety of perspectives.

In this lesson you applied your learning to investigating issues that exist in your local area. You might wish to continue to monitor these issues or to become more involved in acting on them.

Module 5—Hydrocarbons and the Petroleum Industry



Module Summary

In Module 5 you considered the following module questions:

- What is petroleum?
- What does Alberta's petroleum industry do?
- Where do hydrocarbons come from?
- What are hydrocarbons and what makes them such an important class of compounds?
- What are some of the processes that occur within Alberta's petroleum industry?
- What impact does the hydrocarbon industry have on Alberta's economy and environment?

You explored the structure and properties of hydrocarbon molecules, and you learned that natural gas, crude oil, and oil sands are being developed to provide the hydrocarbons used by society.

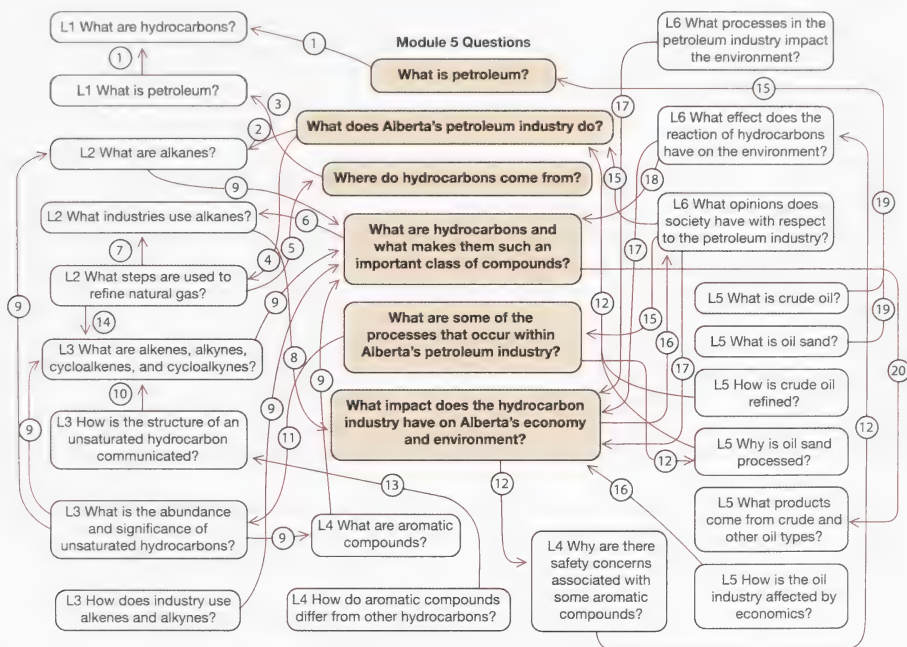
Hydrocarbons are a unique class of molecules that can exist in many forms. In this module you saw that a similar number of carbon and hydrogen atoms can have different arrangements. These arrangements are called isomers. Hydrocarbon molecules, including their isomers, are named according to the systematic naming process, which communicates the important aspects of a molecule's structure.

The structure and arrangement of carbon atoms provide hydrocarbons with unique chemical and physical properties. The natural gas, crude oil, and oil sands refining processes rely on these unique properties and many different reaction types. The physical property of boiling point, for example, is used to refine hydrocarbons.

Concept Map or Graphic Organizer

As you worked through Module 5, you may have added information to a concept map or graphic organizer based on the module and lesson questions listed in the Module 5 Concept Organizer. Now is a good time to review the relationships in your concept map or graphic organizer and to try to answer the module and lesson questions.

A sample Module 5 concept map shows one set of possible links between the questions. Remember that this is one possible description only—there are many other correct possibilities. However, if your completed concept map or graphic organizer differs significantly from the sample, you may wish to contact your teacher or to compare your map or organizer with those of other students in your class. This will ensure that your interpretations of lesson materials and your descriptions are accurate.



Linking Statements

#	Statement
1	source of
2	extract, separate, ship alkanes from petroleum
3	from
4	one example
5	refining produces some alkanes
6	hydrocarbons used by many industries (plastics, solvents)
7	refined products of natural gas used by industry (ethane, plastics)
8	examples of numbers of industries and plants in Alberta
9	type of
10	ending “ene” and “yne;” prefix “cyclo”
11	cracking, reforming increases abundance of some hydrocarbons
12	example of
13	aromatics have chemical formulae like unsaturated hydrocarbons
14	alkenes can be product of natural gas refining (ethene)
15	public opinion
16	influence of economic perspectives
17	influence of ecological perspectives
18	hydrocarbons starting point for many other products
19	one source of
20	economic and technological perspectives suggest



Module Assessment

In this module you investigated the class of molecules called hydrocarbons. In your Module Assessment you will summarize your understanding of the importance of hydrocarbons by preparing a list of five hydrocarbons and their uses. In your list, identify and describe the importance of the five hydrocarbons from a variety of perspectives. You may wish to consult page 45 of the textbook for more information on perspectives.

Use the scoring guide provided to plan your response and to revise your work before submitting it to your teacher.

Save your completed Assessment in your course folder, and submit a copy to your teacher.

Scoring Guide

Score	Scoring Description
4 Standard of Excellence	The response is well organized and presents a correct and comprehensive list of hydrocarbons, their uses, and a description of their importance from all perspectives. The response uses appropriate and clear communication strategies. The description of relevant scientific, technological, and/or societal concepts is explicit. Descriptions, explanations, and/or interrelationships between the concepts provided are correct and reflect a thorough understanding .
3	The response is organized and presents a correct and comprehensive list of hydrocarbons, their uses, and a description of their importance from a range of perspectives. The response uses appropriate and clear communication strategies. The description of relevant scientific, technological, and/or societal concepts is well developed . Descriptions, explanations, and/or interrelationships between the concepts provided are correct and reflect a good understanding .
2 Acceptable Standard	The response is generally organized and presents a correct and comprehensive list of hydrocarbons along with a complete list of their uses. The description of their importance focuses on a limited range of perspectives. The response uses generally clear and adequate communication strategies. The description of relevant scientific, technological, and/or societal concepts is mentioned. Descriptions, explanations, and/or interrelationships between the concepts provided are generally correct and reflect an adequate understanding .
1	The response is poorly organized and presents an incorrect or incomplete list of hydrocarbons and their uses. The description of their importance focuses on a one or two perspectives. The response uses unclear and inadequate communication strategies. The description of relevant scientific, technological, and/or societal concepts is weak or not developed sufficiently . Descriptions, explanations, and/or interrelationships between the concepts provided reflect a poor understanding .
0	The response does not reflect the expectations for a 30-level course.

Module 5 Glossary

alkanes: a class of hydrocarbons that contain only single bonds

alkyl branch: a group of carbon and hydrogen atoms joined by single bonds

The group is not part of the main structure of a hydrocarbon.

aromatics: a class of hydrocarbons in which all hydrocarbons contain benzene or a benzene-like ring

bioremediation: a process that uses natural mechanisms, including bacteria and fungi, to remove toxic materials from soil or water

cycloalkanes: a cyclic (carbon chain forms a circle) hydrocarbon in which all of the bonds between carbon atoms are single bonds

cracking: a process in which larger hydrocarbon molecules are converted into smaller hydrocarbon molecules

hydrocarbon: a compound containing only carbon and hydrogen atoms

petroleum: a mixture of hydrocarbons that is obtained from oil or natural gas

structural isomers: compounds that share the same chemical formula but have different chemical structures

Appendix



Module 5 Self-Check Answers

Contact your teacher if your answers vary significantly from the answers provided here.

Lesson 1

Case Study 1.

- a. Oil sands, natural gas, and conventional crude oil are the most widespread fossil fuel deposits in Alberta.
- b. Coal and coalbed methane are found in Alberta but are not depicted in “Figure 2.”

Case Study 2.

- a. Classically, research was done first and development followed later.
- b. Universities did the research and industry did the development.

Case Study 3.

Processing fossil fuels requires refineries for oil, upgraders for bitumen and heavy oil, processing plants for natural gas, and sorting and crushing facilities for coal. Transportation is mainly by pipelines for oil and natural gas, tanker truck for liquid fuels such as gasoline, and truck (shorter distances) and railcar (longer distances) for coal.

Case Study 4.

The following are examples of trade-offs:

- Positive outcome: Jobs are created by the tar sands industry.
- Negative consequence: When strip mining is used, it degrades the environment.
- Positive outcome: Citizens enjoy the independence and convenience of driving gasoline-powered vehicles.

Section 9.1 1.

- | | |
|--------------|--------------|
| a. inorganic | e. organic |
| b. organic | f. inorganic |
| c. inorganic | g. inorganic |
| d. organic | h. organic |

Section 9.1 2.

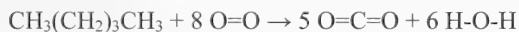
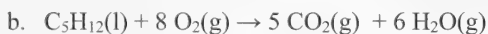
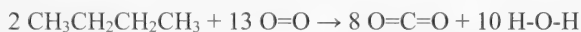
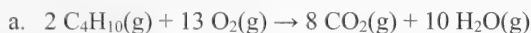
Natural gas, coal, crude oil, heavy oil, oil sands, and coalbed methane are found in Alberta.

Section 9.1 3.

The two major kinds of refining are oil refining and natural gas refining.

Oil refining starts with crude oil or synthetic crude from bitumen. The crude undergoes fractional distillation followed by processing, such as hydrotreating or reforming of some of the fractions. Many products result.

In natural gas refining, the natural gas is condensed, distilled, and processed to remove impurities. The main product is methane gas. Only a few other products result, chiefly ethane, propane, butane, and pentane.

Section 9.1 4.**Section 9.1 5.**

- a. Carbon dioxide is a greenhouse gas. As its concentration in the atmosphere builds up due to the combustion of fossil fuels, the warming effect also increases. Likely this has already affected the global climate and will affect it even more in the future.
- b. $\text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2\text{CO}_3(\text{aq})$
(carbonic acid)

Section 9.1 6.

- | | |
|------------------------|--------------------------|
| a. pro (scientific) | e. con (political) |
| b. pro (technological) | f. pro (legal) |
| c. pro (economic) | g. con (social, ethical) |
| d. con (technological) | h. pro (economic) |

You may have listed other perspectives on some of the statements.

Section 9.1 7.

The two major energy sources are natural gas, which is a fossil fuel, and electricity. Natural gas is used to fuel the furnace and hot water tank and, in some homes, the stove and clothes dryer too. Electricity, which powers lights and appliances, is produced mainly in power plants that burn coal or natural gas.

Your response may be a little different depending on how you interpreted the question's use of the term *energy sources*.

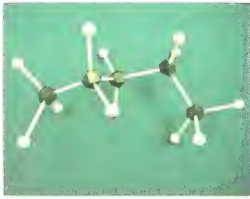
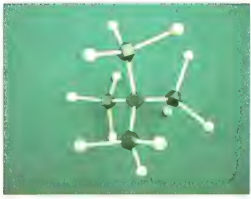
Section 9.1 8.

Solar power, wind power, hydroelectric power, geothermal power, and biomass energy are renewable energy sources naturally available in Alberta. The question asked that you list three of these sources.

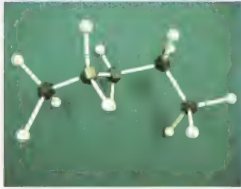
Lesson 2**SC 1.**

Chemical Reaction	Physical (Phase) Change
steps 2, 3, 4	steps 1, 5, 6

SC 2.

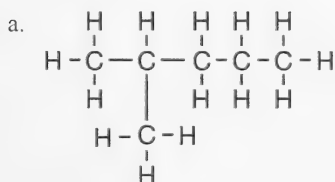
	Forms of C_5H_{12}		
	1	2	3
Picture			
Systematic Name	pentane	2-methylbutane (methylbutane)	2,2-dimethylpropane

SC 3.

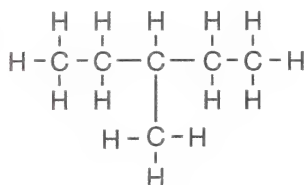
	Forms of C_5H_{12}		
	1	2	3
Picture			
Name	pentane	2-methylbutane (methylbutane)	2,2-dimethylpropane
Structural Formula	$ \begin{array}{ccccccc} & H & H & H & H & H & \\ & & & & & & \\ H & -C & -C & -C & -C & -C & -H \\ & & & & & & \\ & H & H & H & H & H & \end{array} $	$ \begin{array}{ccccccc} & & H & & & & \\ & & & & & & \\ & H & -C & -H & & & \\ & & & & H & H & \\ H & -C & -C & -C & -C & -H \\ & & & & & \\ & H & H & H & H & \end{array} $	$ \begin{array}{ccccc} & H & & & \\ & & & & \\ & H-C-H & & & \\ & & & & \\ H & -C & -C & -C & -H \\ & & & & \\ & H & & H & \\ & & & & \\ & H-C-H & & & \\ & & & & \\ & H & & & \end{array} $
Condensed Structural Formula	$CH_3-CH_2-CH_2-CH_2-CH_3$	$ \begin{array}{c} CH_3 \\ \\ CH_3-CH-CH_2-CH_3 \end{array} $	$ \begin{array}{c} CH_3 \\ \\ CH_3-C-CH_3 \\ \\ CH_3 \end{array} $

SC 4.

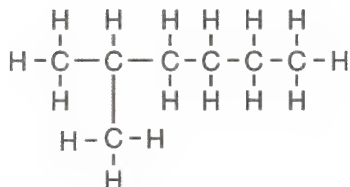
Practice 7.



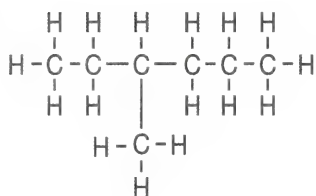
b.



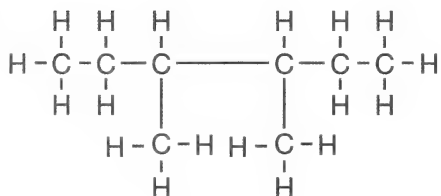
c.



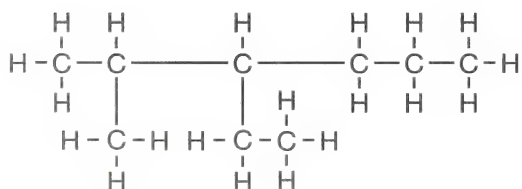
d.



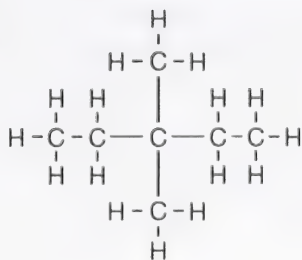
e.



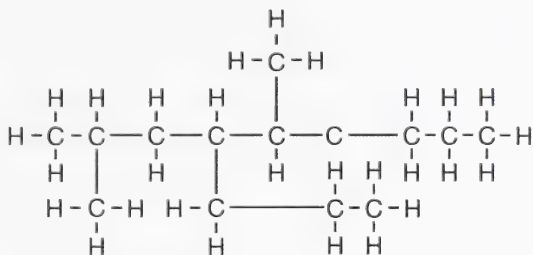
f.



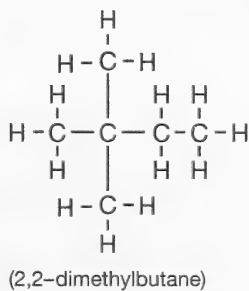
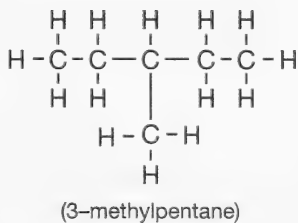
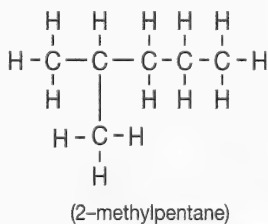
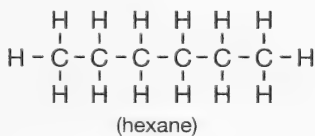
g.



h.

**Practice 8.**

a.



You may have written duplicates that look different. You should have discovered any duplicates when you wrote the names for the isomers.

- b. They are all highly soluble in each other because they are so similar with respect to intermolecular forces. Because they all contain 50 electrons, all are nonpolar and have close to the same London forces.

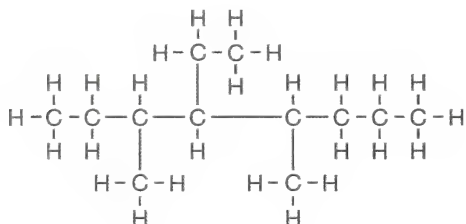
Practice 9.

- 2-methylheptane
- 3,7-dimethylnonane
- 2,4,6-trimethylheptane
- 3-ethyl-6-methyloctane

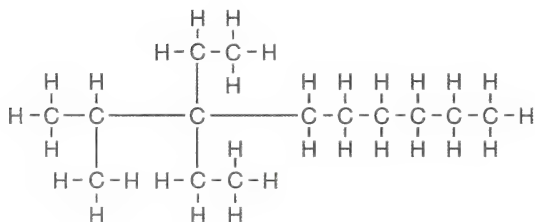
You may have found (b) and (d) tricky because of the way the molecules were written—all of the carbons in the longest chain were not in a horizontal line.

Practice 10.

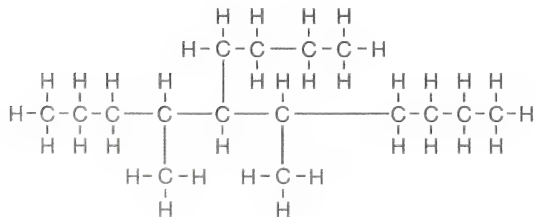
a.



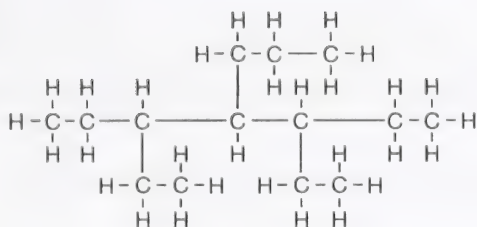
b.



c.



d.

**Practice 11.**

- This is incorrect. A number is required for each branch. The correct name is 2,2 –dimethylhexane.
- This is incorrect. A “di” prefix should be used when two of the same branch are present. The correct name is 3,3 –diethylpentane.
- This is correct.
- This is incorrect. There are four carbons in the longest chain, not three. The correct name is 2,2 –dimethylbutane.
- This is incorrect. There are six carbons in the longest chain, not five. The correct name is 3 –ethylhexane.
- This is incorrect. There are four carbons in the longest chain, not three. The correct name is methylbutane.

SC 5.**Section 9.2 1.**

Methane, ethane, propane, butane, pentanes, and hexanes are typically present in natural gas before it is refined. Natural gas for home heating is almost pure methane because the other components have been removed.

Section 9.2 2.

Sour natural gas contains hydrogen sulfide; sweet natural gas does not. Hydrogen sulfide is a deadly toxin and poses a major safety problem if it is not safely removed.

Section 9.2 3.

To remove alkanes (other than methane) from natural gas, the natural gas is cooled under high pressure so that the alkanes with more than one carbon atom condense to a liquid.

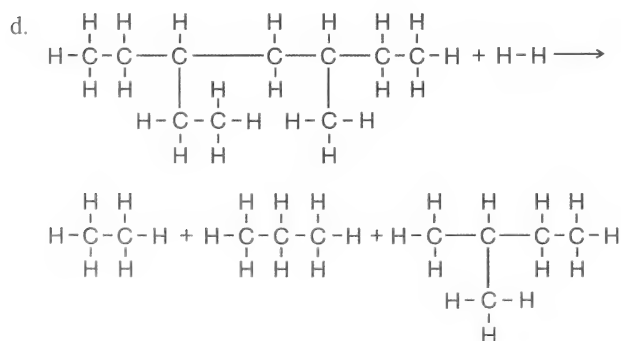
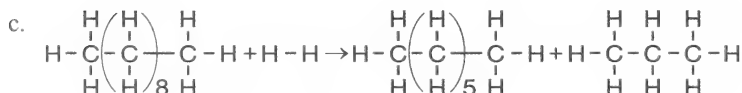
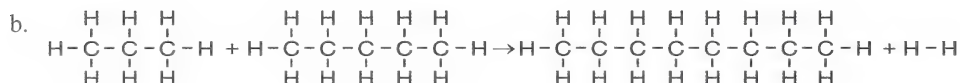
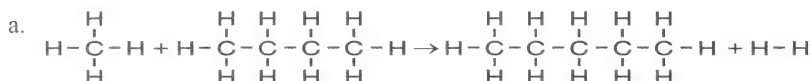
Section 9.2 4.

- a. Two consumer uses for the energy obtained from natural gas are: (1) residential heating and (2) fueling barbecues and campstoves.

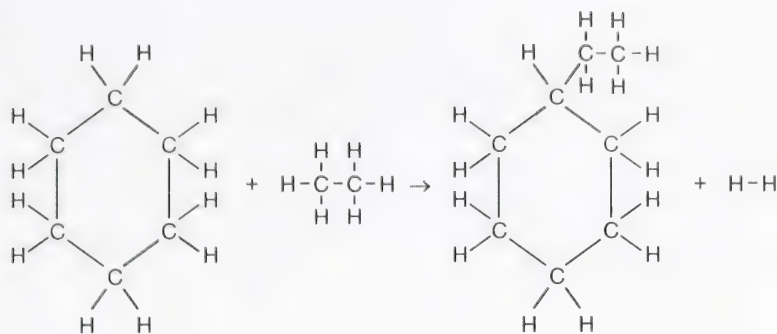
Two commercial uses for the energy obtained from natural gas are: (1) fueling some taxicabs and (2) heating office buildings.

Two industrial uses for the energy obtained from natural gas are: (1) fueling some power plants that produce electricity and (2) separating bitumen from oil sand.

- b. Production of plastic objects, wooden objects, building materials, and paper products require energy from natural gas.

Section 9.2 5.

e.

**Section 9.2 6.**

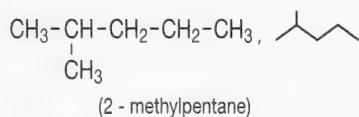
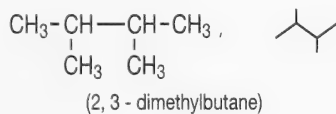
- ethylpentane
- trimethylbutane
- 3-ethyl-3,5-dimethylhexane
- 3-methyl-5-propyloctane

While the numbers are unnecessary, it is acceptable if you named (a) as 3-ethylpentane and (b) as 2,2,3-trimethylbutane.

Section 9.2 7.

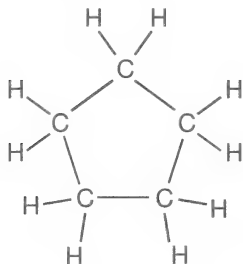
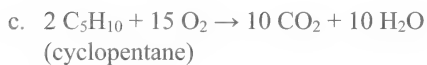
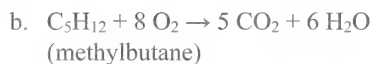
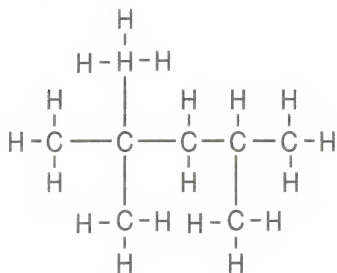
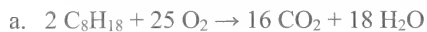
- propane + pentane $\rightarrow$ octane + hydrogen
- hexane $\rightarrow$ 2,2-dimethylbutane

c.



The names are 2,3-dimethylbutane and 2-methylpentane. You may also have used methylpentane as one isomer.

Section 9.2 8.



Section 9.2 9.

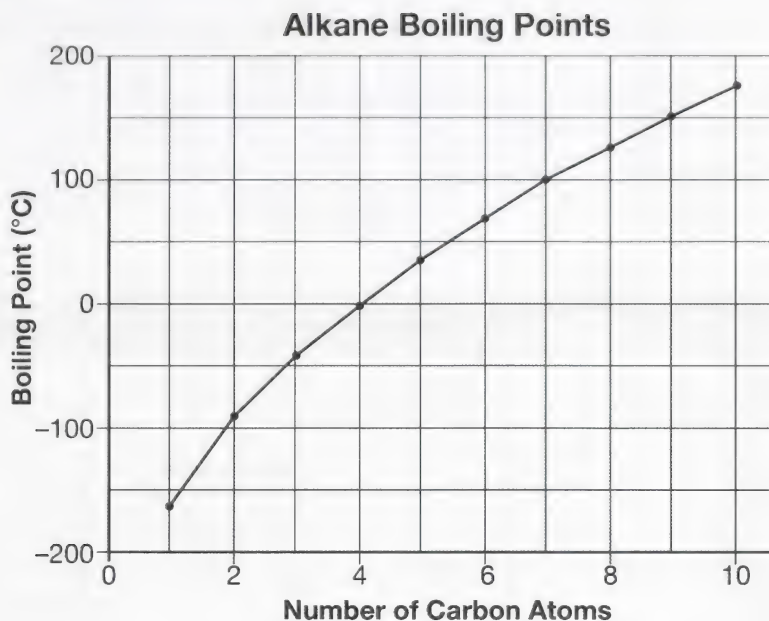
Economic: Developing petroleum resources can be valuable as petroleum is a valuable commodity.

Political: The oil industry is a major employer, so the government encourages exploration and development.

Militaristic: Having a secure supply of oil is vitally important in warfare.

Section 9.2 10.

a.



The data points on the graph have been connected with straight lines because the function is non-continuous.

The boiling point is directly proportional to the number of carbon atoms in the alkane. The relationship is almost linear. This is because the London forces become stronger with the increasing number of electrons, and the number of electrons increases by eight with each successive alkane.

- b. Methane is used for home heating. Methane is easy to deliver by pipeline.

Ethane is used to make polyethylene. Polyethylene is readily available from natural gas.

Propane is used as a barbecue fuel. Propane is easily condensed with pressure for storage in a tank.

Butane is used as a propellant in aerosol sprays. Butane vapourizes when the pressure is released on the aerosol container's contents.

Pentane is used as a solvent. It dissolves most nonpolar organic compounds.

Hexane is used as a component of gasoline. Hexane burns well.

Heptane is used as an organic solvent. Heptane is easy to store and transport.

Octane is a component of gasoline. Branched octanes have high octane numbers.

Nonane and decane are components of diesel fuel; they are not too volatile and they burn well.

You may have identified other uses, especially for the smaller alkanes.

Lesson 3

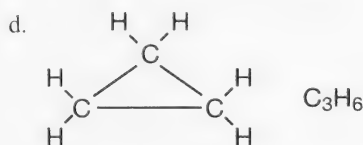
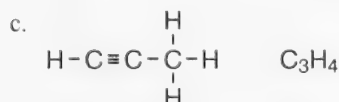
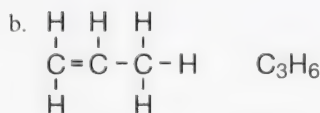
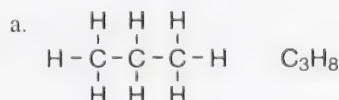
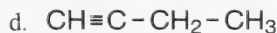
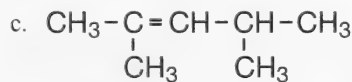
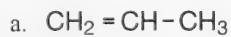
SC 1.

	Isomer of C_4H_8			
Structural Formula	$\begin{array}{c} \text{H} & \text{H} & \text{H} \\ & & \\ \text{H}-\text{C}=\text{C}-\text{C}-\text{C}-\text{H} \\ & & \\ \text{H} & \text{H} & \text{H} \end{array}$	$\begin{array}{c} \text{H} & \text{H} & \text{H} \\ & & \\ \text{H}-\text{C}-\text{C}=\text{C}-\text{C}-\text{H} \\ & & \\ \text{H} & \text{H} & \text{H} \end{array}$	$\begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\text{H} \\ \\ \text{H}-\text{C}=\text{C}-\text{C}-\text{H} \\ \\ \text{H} \end{array}$	$\begin{array}{c} \text{H} & \text{H} \\ & \\ \text{H}-\text{C}-\text{C}-\text{H} \\ & \\ \text{H}-\text{C}-\text{C}-\text{H} \\ & \\ \text{H} & \text{H} \end{array}$
Condensed Structural Formula	$\text{CH}_2=\text{CH}-\text{CH}_2-\text{CH}_3$	$\text{CH}_3-\text{CH}=\text{CH}-\text{CH}_3$	$\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_2=\text{C}-\text{CH}_3 \end{array}$	$\begin{array}{c} \text{CH}_2-\text{CH}_2 \\ \quad \\ \text{CH}_2-\text{CH}_2 \end{array}$
Line Diagram				
Name	butene (but-1-ene)	but-2-ene	2-methylpropene	cyclobutane
Type of Hydrocarbon	alkene	alkene	alkene	cycloalkane

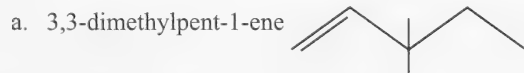
SC 2.

Practice 1.

- alkene (C_nH_{2n})
- alkane (C_nH_{2n+2})
- alkyne or cycloalkene (C_nH_{2n-2})
- alkene or cycloalkane (C_nH_{2n})

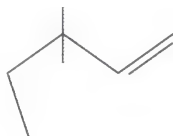
Practice 2.**Practice 3.****Practice 4.**

It is not necessary to use a number in the name to indicate the position of a multiple bond because, with a three-carbon chain, the multiple bond can only be on an end carbon.

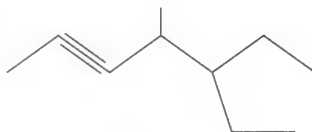
Practice 5.

Hydrocarbons and the Petroleum Industry

b. 3,3-dimethylpent-1-ene

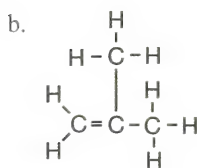
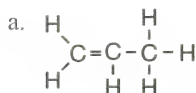


c. 5-ethyl-4-methylhept-2-yne



While a and b are drawn differently, they are, in fact, the same compound.

Practice 7.

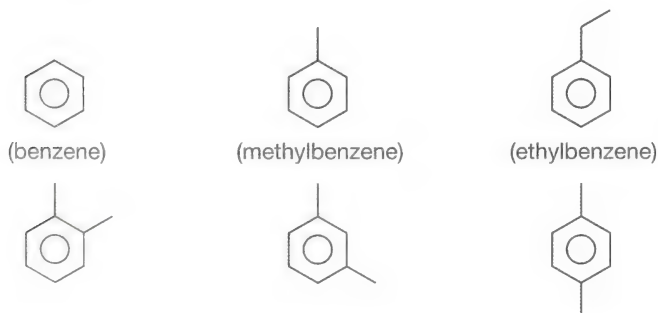


Lesson 4

Section 9.4 1.

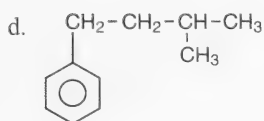
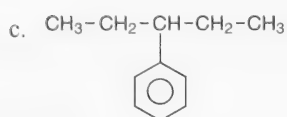
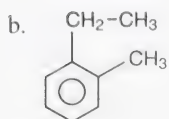
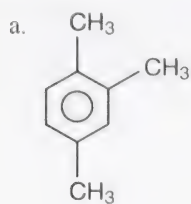
Benzene, C_6H_6 , is the simplest aromatic compound. Its carbon-carbon bond lengths are all the same, but they are neither single nor double bonds. Each pair of carbons shares one electron pair, and the six remaining valence electrons are shared around the ring.

Section 9.4 2.

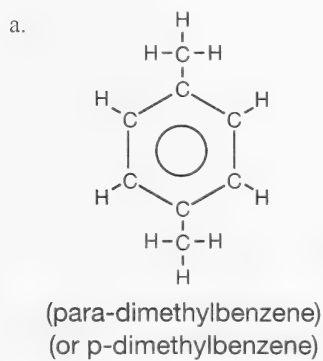


(1, 2—dimethylbenzene) (1, 3—dimethylbenzene) (1, 4—dimethylbenzene)

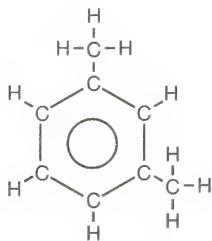
Section 9.4 3.



Section 9.4 4.

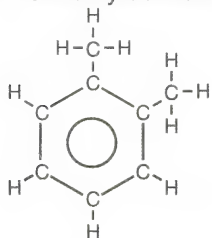


b.



(meta-dimethylbenzene)
(or m-dimethylbenzene)

c.



(ortho-dimethylbenzene)
(or o-dimethylbenzene)

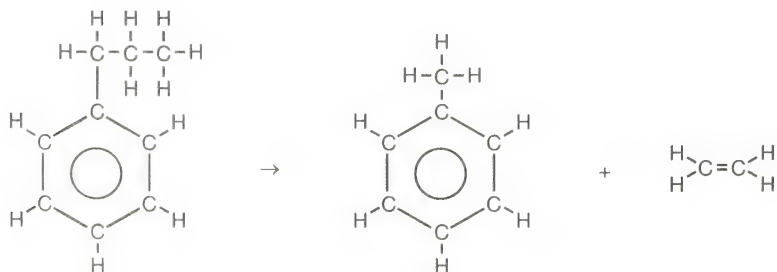
Section 9.4 5.

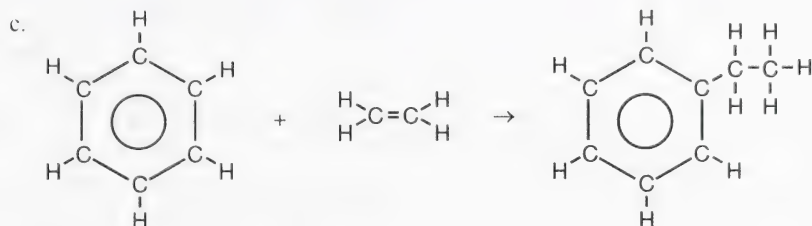
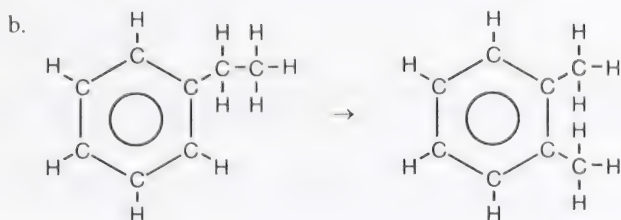
- 1-ethyl-3-methylbenzene
- 1-methyl-4-propylbenzene
- 3-methyl-2-phenylpentane
- 3-methyl-4-phenylhexane
- 2-phenylhept-3-ene
- 4-phenylpent-1-yne

You may not have recognized C_6H_5 as being a phenyl group in part c. and you might have incorrectly named the aromatic hydrocarbon in part d. as 2-ethyl-3-phenylpentane.

Section 9.4 6.

a.



**Section 9.4 7.**

- aliphatic
- aromatic
- aliphatic
- aliphatic
- aromatic
- aromatic

Section 9.4 8.

- unsaturated
- saturated
- unsaturated
- unsaturated
- unsaturated
- unsaturated

Section 9.4 9.

As pointed out in “Section 9.4” question 1, benzene does not have any double bonds as such. The name 1,3,5-cyclohexatriene would be misleading and incorrect.

Section 9.4 10.

A major factor in determining the strength of London forces is the number of electrons in a molecule. The greater the number of electrons, the stronger the London forces and the higher the boiling point. Using only this criterion, the following order of increasing boiling points would be predicted:

benzene (42 e⁻) < cyclohexene (46 e⁻) < cyclohexane (48 e⁻) < hex-1-ene (48 e⁻) < hexane (50 e⁻)

The actual order is as follows:

hex-1-ene (63.5°C) < hexane (68.7°C) < benzene (80.10°C) < cyclohexane (80.5°C) < cyclohexene (83.0°C)

Since the predicted order is not consistent with the evidence, it is not valid to consider only the number of electrons when predicting boiling points. Here, molecular shape is important because it affects how closely the molecules can get to one another.

Lesson 5

SC 1.

Practice 1.

Both a fractionation tower and a laboratory-scale distillation apparatus use a heat source to boil off components of a mixture. Both employ a vertical column to more efficiently separate and collect the fractions obtained by condensing them.

In a fractionation tower, the mixture is continuously fed in, and the fractions condense simultaneously at various levels in the tower. In the lab-scale process, a mixture is placed in the flask and the components are distilled and condensed one at a time.

Practice 2.

- Crude oil is heated in the absence of air in the fractionation tower because, at such a high temperature, the oxygen in the air would cause the crude oil to burn.
- $$\text{C}_5\text{H}_{12}(\text{l}) + \text{heat} \rightarrow \text{C}_5\text{H}_{12}(\text{g})$$
$$\text{C}_8\text{H}_{18}(\text{l}) + \text{heat} \rightarrow \text{C}_8\text{H}_{18}(\text{g})$$
- $$\text{C}_5\text{H}_{12}(\text{g}) \rightarrow \text{C}_5\text{H}_{12}(\text{l}) + \text{heat}$$
$$\text{C}_8\text{H}_{18}(\text{g}) \rightarrow \text{C}_8\text{H}_{18}(\text{l}) + \text{heat}$$
- Octane has a higher boiling point than pentane because octane's London forces are stronger, mainly due to octane's greater number of electrons (66 e⁻ versus 42 e⁻).
- Pentane rises higher in the tower than octane.

Practice 3.

The fractions used for cracking stock are kerosene, fuel oil, gas oil, and greases. Cracking changes products that are in less demand into products that are in greater demand. Cracking also results in products that give a greater monetary return to the refinery.

Practice 4.

Approximately 95% of petroleum is used as fuel. The major fuel produced is gasoline.

Practice 5.

- Straight-run gasoline contains hydrocarbons with five to 12 carbon atoms, which is more than the lighter fractions but less than the heavier fractions.
- $$\text{C}_5\text{H}_{12}(\text{g}) + 8 \text{O}_2(\text{g}) \rightarrow 5 \text{CO}_2(\text{g}) + 6 \text{H}_2\text{O}(\text{g})$$

$$2 \text{C}_8\text{H}_{18}(\text{g}) + 25 \text{O}_2(\text{g}) \rightarrow 16 \text{CO}_2(\text{g}) + 18 \text{H}_2\text{O}(\text{g})$$

It is assumed the fuel is vapourized before burning in the cylinder.

Practice 6.

- The hydrocarbons are all similar nonpolar molecules, so they are mutually soluble.
- Water molecules are very unlike hydrocarbons in that water is a highly polar hydrogen-bonded substance. There is little tendency for the crude oil solution to dissolve any water.

SC 2.**Practice 8.**

If only physical means were used to refine oil, there would be too much of the heavier fractions produced, and the supply of products such as gas oil and greases would exceed the demand. Also, straight-run gasoline is of lower quality than gasoline containing compounds produced by reforming and alkylation.

Practice 9.

- $\text{CH}_3-(\text{CH}_2)_{16}-\text{CH}_3 \rightarrow \text{CH}_3-(\text{CH}_2)_6-\text{CH}_3 + \text{CH}_3-(\text{CH}_2)_7-\text{CH}_3 + \text{C}$
- $\text{CH}_3-(\text{CH}_2)_8-\text{CH}_3 \rightarrow \text{CH}_3-(\text{CH}_2)_3-\text{CH}_3 + \text{CH}_3-(\text{CH}_2)_2-\text{CH}_3 + \text{C}$
- $\text{CH}_3-(\text{CH}_2)_{14}-\text{CH}_3 \rightarrow \text{CH}_3-(\text{CH}_2)_7-\text{CH}_3 + \text{CH}_3-(\text{CH}_2)_4-\text{CH}_3 + \text{C}$

Practice 10.

Hydrocracking is carried out on heavier fractions, whereas catalytic reforming is done on lighter fractions. The processes complement each other because both improve the quality of the gasoline produced at the refinery.

Practice 11.

Alkylation increases the amount of branching within the molecules. Catalytic reforming provides an increase in the amount of aromatic molecules in the gasoline.

Practice 12.

- $\text{CH}_3-(\text{CH}_2)_4-\text{CH}_3 + \text{H}_2 \rightarrow \text{CH}_3-\text{CH}_3 + \text{CH}_3-\text{CH}_2-\text{CH}_2-\text{CH}_3$
- $\text{CH}_3-\text{CH}(\text{CH}_3)-\text{CH}_2-\text{CH}_2-\text{CH}_3 + \text{H}_2 \rightarrow \text{CH}_3-\text{CH}_2-\text{CH}_3 + \text{CH}_3-\text{CH}_2-\text{CH}_3$
- $\text{CH}_3-\text{C}(\text{CH}_3)_2-\text{CH}_2-\text{CH}_3 + \text{H}_2 \rightarrow \text{CH}_3-\text{CH}_3 + \text{CH}_3-\text{CH}(\text{CH}_3)-\text{CH}_3$

Practice 13.

- a. propane + pentane $\rightarrow$ 2,2,4-trimethylpentane + hydrogen
- b. $\text{CH}_3\text{-(CH}_2\text{)}_6\text{-CH}_3 \rightarrow \text{CH}_3(\text{C}_6\text{H}_4)\text{CH}_3 + 4 \text{ H}_2$
- c. pentane $\rightarrow$ ethylcyclopropane + hydrogen

You may have discovered that it is not obvious that $\text{C}_3\text{H}_5(\text{C}_2\text{H}_5)$ is a cyclic compound.

- d. $\text{CH}_3\text{-(CH}_2\text{)}_8\text{-CH}_3 \rightarrow \text{CH}_3\text{-CH(CH}_3\text{)-CH(C}_2\text{H}_5\text{)-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_3$

Practice 14.

- a. Benzene has the molecular formula C_6H_6 , which gives an H:C ratio of 1:1. Even with alkyl groups attached, the ratio remains close to 1:1.
- b. Alkanes, alkenes, and large alkynes have a ratio close to 2:1.
- c. In hydrocracking, as aromatics are converted to aliphatic compounds, hydrogen is added but no carbon is removed. As a result, the H:C ratio must increase. For aromatics, the ratio increases from approximately 1:1 to approximately 2:1.

Practice 15.

Hydrocracking produces a product with a higher H:C ratio than catalytic cracking and does not produce coke (carbon), an undesirable by-product.

SC 3.

Sample Solution

Responses may include any aliphatic or aromatic hydrocarbons of between five to 12 carbons each. Alkanes, alkenes, cycloalkanes, cycloalkenes, and aromatic compounds are all possible answers. To check the accuracy of the chemical structures you have drawn, you may wish to check the chemical structures shown in the textbook.

Lesson 6

SC 1.

complete combustion: $\text{C}_5\text{H}_{12}(\text{l}) + 8 \text{ O}_2(\text{g}) \rightarrow 5 \text{ CO}_2(\text{g}) + 6 \text{ H}_2\text{O}(\text{g})$

incomplete combustion: $2 \text{ C}_5\text{H}_{12}(\text{l}) + 11 \text{ O}_2(\text{g}) \rightarrow 10 \text{ CO}(\text{g}) + 12 \text{ H}_2\text{O}(\text{g})$
(one of many possible equations)

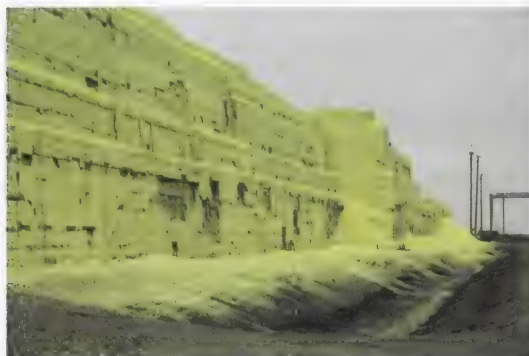
In the first equation 8 mol of O_2 are required per mol of pentane. In the second equation 5.5 mol of O_2 are required per mol of pentane. Complete combustion generally requires more oxygen than incomplete combustion.

SC 2. Many hydrocarbons are present in exhaust from both fuel types, but the percentage of each compound can be quite low. Depending upon the composition of the fuel in the research collected, benzene and toluene are present at relatively high levels. You may have identified the following trends:

- Diesel produces a greater percentage of black carbon (soot) and polycyclic aromatic hydrocarbons (PAH) than gasoline.
- Gasoline tends to produce a higher quantity of smaller hydrocarbons, which is not surprising considering gasoline is composed of hydrocarbons from a fraction of refined oil that has fewer carbons than diesel fuel.

SC 3. Elemental sulfur is a product of the treatment process. Because of the large volume of gasoline produced, a large quantity of elemental sulfur is also produced. The sulfur is often stored outdoors in large blocks, which become extremely large over time.

As shown in the picture, because of their exposure to wind, rain, and snow, blocks can erode over time. The picture also shows a plastic-lined trench designed to collect water that drains from the block. The plastic lining prevents the water from seeping into the underlying soil. If it is not contained, water in this trench could become acidified and could pose a threat to biological systems.



Chemistry 30

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Petrochemicals

Module 6

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Module 6—Petrochemicals

Module Introduction

In many centres in Alberta, there are areas often called “Refinery Row.” Along these roadways are many large, industrial complexes like the one pictured. In Module 5 you learned that refineries are used to process mixtures of hydrocarbons. As you will learn in this module, many of the facilities that people call refineries are not that at all—rather, they are petrochemical facilities, and they are at the core of Alberta’s petrochemical industry.



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In the petrochemical industry, hydrocarbons are converted into other chemicals using a variety of chemical reaction processes. Some of these reaction types change hydrocarbons into related molecules that contain oxygen and other atoms. The resulting compounds have unique physical and chemical properties that make them useful materials for everyday products.

In Module 6 you will investigate the following questions:

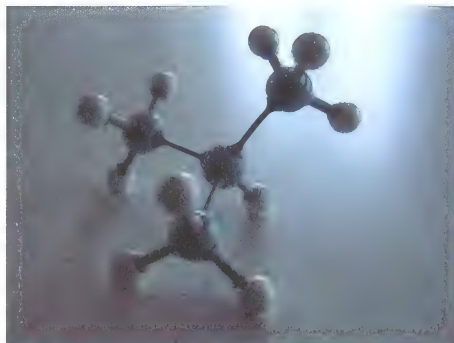
- What kinds of chemical reactions are used to manipulate hydrocarbons in order to produce petrochemicals?
- How has the chemical industry responded to concerns about the environment?
- What are some of the processes that occur within Alberta’s petrochemical industry?



Big Picture

In this module you will focus on the types of chemical reactions used to convert hydrocarbons into other classes of organic compounds. These kinds of reactions are the basis of the petrochemical industry. Like most industries, the petrochemical industry is interested in “greening” its practices—making them more environmentally friendly.

As you work through this module you will investigate how the chemical industry is adapting its processes to reduce the industry’s



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This is a ball and stick model for the hydrocarbon molecule 2-methylpropane.

impact on the environment. Some practices to consider when greening chemical processes are as follows:

- Prevent waste.
 - Design processes that reduce or even prevent waste, have fewer by-products and more of the original material in the final product (atom economy), and use renewable materials in processes.
 - Develop materials that will degrade after use by natural processes (sunlight or biodegradation)
- Reduce the toxicity of compounds.
 - Design processes that involve less toxic materials, including solvents.
 - Design processes so that by-products have low toxicity.
- Improve efficiency. Efficiency can be improved in two ways:
 - Strive for fewer by-products and less waste products (improved atom economy).
 - Increase the use and development of catalysts to reduce energy requirements for reactions.
- Consider safety.
 - Design systems to reduce the potential for accidents and accidental exposure.

You will also learn how the green practices described are applied to chemical reactions—both the kind you will carry out in a laboratory and those that occur in petrochemical facilities.



Assessment in This Module

Each lesson contains a range of activities and assessment options. These include assignments, labs, and Self-Check, Try This, Discuss, Reflect and Connect, and Reflect on the Big Picture activities. Instructions will be provided for each of these activities so that you can appropriately focus your time and effort. Your teacher will tell you which assessment options to complete and which responses to submit for marks or feedback. Remember to save all of your work in your Chemistry 30 folder.

Aspirin (Acetylsalicylic acid, or ASA) is one of the most common drugs in the world. Aspirin can be made from compounds found in petroleum or from another starting point. At the completion of Module 6 you will use the knowledge of organic reactions you gain in this module to analyze two possible processes for manufacturing Aspirin. The Module 6 Assessment is done as part of the Unit Assessment. You may wish to look at the Unit Assessment before starting Lesson 1.

In This Module

Lesson 1—Petrochemicals in Alberta

In Module 5 you learned about Alberta's petroleum reserves, but did you realize that more can be done with the petroleum? Alberta is Canada's leading petrochemical manufacturer. The petrochemical industry is Alberta's second largest industry, and it is worth \$14 billion! In Lesson 1 you will begin to explore the petrochemical industry.

You will investigate the following lesson questions:

- What are petrochemicals?
- What kinds of products result from Alberta's petrochemical industry?

Lesson 2—Organic Halides

Among the most-used classes of petrochemicals are the organic halides. Organic halides are used in many applications, including refrigerants and in the production of plastics. In Lesson 2 you will learn how these halogen-containing molecules are made and used.

You will investigate the following lesson questions:

- What are organic halides?
- In what reactions are organic halides involved?

Lesson 3—Alcohols

You may have purchased blended gasoline recently. Gasoline can be mixed with ethanol to make blended gasoline. Ethanol is one member of a group of molecules called alcohols. Alcohols have many uses in manufacturing. As a result of their properties, alcohols are one of the most-produced petrochemicals. In Lesson 3 you will learn about the production and properties of alcohols like ethanol.

You will investigate the following lesson questions:

- What are alcohols?
- Are alcohols being produced and used in a responsible way?

Lesson 4—Carboxylic Acids and Esters

In Lesson 3 you learned about alcohols, a group of organic compounds that have a functional group containing oxygen. In Lesson 4 you will learn about two more classes of organic compounds—carboxylic acids and esters—and how the oxygen in their functional groups is critical to their chemical and physical properties.

You will investigate the following lesson questions:

- What are carboxylic acids and esters?
- How are carboxylic acids and esters involved in the petrochemical industry?

Lesson 5—Addition Polymers

Vinyl and polyethene are names you probably recognize as types of plastics. You may already know that there are many different types of plastics, each with different properties and uses. Vinyl and polyethene can only be made from certain types of petrochemicals using a specific type of reaction. In Lesson 5 you will learn about the kinds of plastics that are created using an addition reaction.

You will investigate the following lesson questions:

- What is the process used to make plastic?
- What properties must molecules have if they are to be used in making plastic?

Lesson 6—Condensation Polymers

Natural polymers include proteins, lipids, carbohydrates, and starches. In Lesson 6 you will learn how these molecules are created by polymerization reactions. You will also learn how synthetic polymers can be made using the same functional groups.

You will investigate the following lesson questions:

- How do natural and synthetic polymers compare?
- What are other reaction mechanisms by which polymers can be made?

Module 6—Petrochemicals

Lesson 1—Petrochemicals in Alberta

**Get Focused**

In the previous module you recorded signs of activity associated with the petroleum industry. You may have identified local businesses or activities in your community that use petroleum to make other products. If Alberta has a source of petroleum, it makes sense that the province should also have a lot of industry that uses petroleum.

Alberta's petrochemical industry is a very large sector of the provincial economy. It is estimated that over 7000 jobs are directly related to the petrochemical industry. You know that chemical engineers and technologists are required to operate petrochemical plants like the one pictured. However, when you consider the construction and maintenance of facilities and the support required to keep a workforce busy, you realize how many more people are indirectly employed by the petrochemical industry.



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You have recently learned that petroleum involves many different kinds of molecules, but what happens in the petrochemical industry to the molecules in petroleum? In this lesson you will begin to investigate the petrochemical industry.

Consider the following questions as you complete Lesson 1:

- What are petrochemicals?
- What kinds of products result from Alberta's petrochemical industry?



Module 6: Lesson 1 Assignment

You will be directed to go to the Assignment Booklet to complete the Module 1: Lesson 1 Assignment later in this lesson.

Later in this lesson you will also begin to record evidence and arguments from a variety of perspectives on the use of hydrocarbons as petrochemicals or as fuel. This list will be important in completing the final assessment in this module, which takes place at the end of Lesson 6.

The other questions in this lesson are not marked by the teacher; however, you should still answer these questions. The Self-Check, Try This, and other types of questions are placed in this lesson to help you review important information and build key concepts that may be applied in future lessons. You should record the answers to all the questions in the lesson and place those answers in your course folder.

After a discussion with your teacher, you must decide what to do with the questions that are not part of your assignment. For example, you may decide to submit the responses to Try This and other questions that are not marked to your teacher for informal assessment and feedback. Your answers are very important to your teacher. They provide your teacher with information about your learning, and they help your teacher identify where adjustments to your instruction may be necessary.



Explore

In Module 5 you learned about hydrocarbons. The properties of hydrocarbon molecules make the molecules useful for a variety of processes. What do you know about these processes? Complete TR 1 to find out.



Try This

TR 1. Complete “Starting Points” questions 1–3 on page 410 in the textbook. Save a copy of your answers in your course folder. Don’t worry if you don’t know the answers right now—just answer each question to the best of your ability. Later in this module you will have an opportunity to revise your answers before sharing them.



Self-Check

As you get started in this module, it is important that you recall information from Module 5. You will build on that information in Module 6. Refresh your memory by completing SC 1.

SC 1. Complete “Practice” questions 1–3 on page 412 of the textbook.

Check your work with the answer in the appendix.



Try This

TR 2. Read through “Exploration” on page 411 in the textbook. As you work through Module 6 you will learn more about the use of molecules from petroleum. Create a document in your course folder. In this document you will record evidence and arguments from a variety of perspectives that address the resolution stated in “Exploration.” Save your document in your course folder. Later you will summarize how this issue is viewed from various perspectives.



Read

Read pages 412–413 in the textbook.



Self-Check

Go to the Assignment Booklet. At the end of the Assignment Booklet are the structural formulae of the molecules listed in “Figure 2” on page 413 of the textbook. You may wish to use these structural formulas to answer SC 2.

SC 2. Begin your investigation of chemical reactions involved in converting petroleum into petrochemicals by answering “Practice” questions 5 and 7 on page 414 in the textbook.

Check your work with the answer in the appendix.

Petrochemicals

In Alberta, the two main sources for hydrocarbons are natural gas and crude oil. Currently 95% of the natural gas and crude oil harvested is burned as an energy source. The remaining 5% is used as feedstock to create **petrochemicals**.

petrochemical: a chemical made or extracted from petroleum

Petrochemicals include any chemicals produced from petroleum. Examples of petrochemical products include plastics, synthetic clothing, shingles, cosmetics, paint, carpets, fertilizers, adhesives, and even pharmaceuticals. The petrochemical industry is considered a secondary or tertiary industry because it takes raw materials and creates products or intermediaries from them.

Primary petrochemicals are raw chemicals that are recovered from the earth. For example, you will recall from Module 5 that ethane is a component of natural gas. It is used as feedstock to create ethene through ethane cracking. Ethene has some uses, such as ripening fruit, but most ethene is further processed to create other petrochemicals.



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Read

Read pages 414–416 in the textbook.



Try This

Identifying Additional Perspectives

It appears that you are living in the “Age of Oil” but, given that petroleum reserves are not infinite, there is a great deal of concern about what is being done with the resources that remain. Retrieve the document you created earlier in this lesson to record perspectives, evidence, and arguments on whether society should be saving more fossil fuels for future use as petrochemicals.

TR 3. Use the Internet to find more information on this subject. Remember to include audio and video from respected sources in your search to make sure you find documentaries and programs of interest. Try the search term “audio + CBC + age of oil” in a search engine. Review one of the websites your search returns. In your document, record the perspectives introduced and the supporting evidence and arguments. Save your work in your course folder.



Self-Check

As you found in the last module, the ability to represent organic molecules as chemical structures is very important.

SC 3. Complete “Section 10.1” question 1 on page 416 of the textbook. You may wish to use molecular models when completing this question. If you are using materials in your home or classroom to build your models, remember that each carbon atom makes four bonds, each hydrogen and chlorine atom makes one bond, and each oxygen atom can make two bonds to other atoms.

SC 4. Complete “Section 10.1” question 2 on page 416 of the textbook to add to your research on the petrochemical industry and the use of petroleum. What perspective is represented in this question?

Check your work with the answer in the appendix.



Discuss

Is society close to running out of crude oil? What will be the consequences when the crude oil supply is depleted? In this lesson you have been exposed to different perspectives on these questions.

D 1. Write a few paragraphs about your opinion on these questions, and post them to the discussion area for your class. Read the responses of at least two other students. Compare those responses to your own, and identify similarities and differences between them. Save a copy of your opinion and the similarities and differences you identified in your course folder.



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Module 6: Lesson 1 Assignment

Open the Assignment Booklet. Complete “Module 6: Lesson 1 Assignment.”



Reflect on the Big Picture

The plastic shopping bag is such a convenient and common item. Have you noticed recently that some stores are charging you if you want a plastic bag or are encouraging you to purchase a reusable bag made of other materials? The plastic shopping bag frequently ends up in landfills or as litter and can take thousands of years to degrade.

Some cities in Alberta are considering placing a ban or a tax on plastic shopping bags. It is hoped that this approach might significantly reduce the amount of plastic entering landfills. Plastic shopping bags like the one pictured here are



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made from the petrochemical polythene. Polythene is derived from ethane present in natural gas or is produced by cracking crude oil.

Does society's current use of plastic bags represent an intelligent use of petrochemicals and natural resources? Does charging for, taxing, or banning the use of plastic shopping bags promote a more intelligent use of petrochemicals and petroleum?



Discuss

D 2. Respond to the questions listed in Reflect on the Big Picture. Post your response in the discussion area for your class. Read the responses of at least two other students in your class. Share your thoughts on the responses submitted by other students and, if necessary, revise your response. Save a copy of your response in your course folder.



Module 6: Lesson 1 Assignment

You've already completed the Module 6: Lesson 1 Assignment. Before finishing this lesson, make sure you have updated and saved information in your document on perspectives, evidence, and arguments regarding the use of hydrocarbons as petrochemicals or as fuel.



Lesson Summary

In Lesson 1 you considered the following questions:

- What are petrochemicals?
- What kinds of products result from Alberta's petrochemical industry?

Hydrocarbons found in petroleum can be modified to create new substances. Approximately 5% of the natural gas and crude oil harvested in Alberta is used as feedstock to create petrochemicals. Petrochemicals include all chemicals that are produced from petroleum. Plastics, synthetic clothing, shingles, cosmetics, paint, carpets, fertilizers, adhesives, and pharmaceuticals are examples of petrochemical products.

Petrochemicals are one way to use the hydrocarbons found in petroleum. As you work through Module 6 you will continue to collect information and consider different perspectives on how society can best use the hydrocarbons found in petroleum.

Lesson Glossary

petrochemical: a chemical made or extracted from petroleum

Module 6—Petrochemicals

Lesson 2—Organic Halides



Get Focused

Hey, teenagers are still growing, and they are often hungry. So it makes sense that the refrigerator door might be the first door you open in the morning and the last door you close at night. At one time, homes relied on an icebox and daily deliveries of ice to refrigerate food. Today, refrigeration is a heavily relied-upon technology.

Did you know that the technology used to operate a modern refrigerator relies on the energy change that occurs when certain molecules undergo a phase change? This technology goes back to the mid-1700s. Unfortunately, the first refrigerants (like diethyl ether and ammonia) posed a health risk and were not the safest substances to use.



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In a quest to find safer refrigerants, a class of organic compounds called **chlorofluorocarbons (CFCs)** were developed and tested. The first CFCs were found to have chemical and physical properties suitable for use in refrigeration systems, and they were non-toxic. As a result, CFCs were quickly adopted for use as refrigerants.

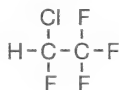
chlorofluorocarbons (CFCs): a group of organic compounds composed of carbon, hydrogen, chlorine, and fluorine

Consider the structural formulae for two CFCs:

(a) dichlorodifluoromethane



(b) 2-chloro-1,1,1,2-tetrafluoroethane



CFCs and other organic molecules can contain halogens. In Lesson 2 you will learn about organic halides, including how they are made and used. Organic halides are halogen-containing organic molecules.

Consider the following questions as you complete Lesson 2:

- What are organic halides?
- In what reactions are organic halides involved?



Module 6: Lesson 2 Assignment

There is no assignment for this lesson. However, you will be asked to submit samples of your work to your teacher where instructed.

You must decide what to do with the questions that are not marked by the teacher.

Remember that these questions provide you with the practice and feedback that you need to successfully complete this course. You should respond to all the questions and place those answers in your course folder.



Explore

In Lesson 1 you examined the chemical structures of many petrochemicals, and you organized the petrochemicals into groups. Can you recall what strategy you used to group these molecules? Did your strategy involve grouping all the molecules that had halogen atoms into one group and all the structures with oxygen atoms into another group? If so, you were grouping the petrochemicals into **hydrocarbon derivative** families.

Atoms other than carbon or hydrogen, or the presence of multiple bonds between carbon atoms in a hydrocarbon, create a **functional group**. In this module you will learn about the functional groups present in common petrochemical compounds.

You may recall from “Figure 2” on page 413 that petrochemical derivatives are created by altering hydrocarbons (or primary petrochemicals). Compare the following two illustrations:

hydrocarbon derivative: a molecular compound of carbon, at least one other element, and, usually, hydrogen

functional group: a characteristic arrangement of atoms or bonds within a molecule that determines the most important chemical and physical properties of a class of compounds

Hydrocarbon	Petrochemical Derivative
methane $ \begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\text{H} \\ \\ \text{H} \end{array} $	methyl halide $ \begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\text{Cl} \\ \\ \text{H} \end{array} $

How could you use the hydrocarbon on the left to create the molecule on the right? Describe the changes that need to occur to make the molecule on the left transform into the one on the right.

Organic compounds that contain halogen atoms are grouped as **organic halides**. Organic halides contain one or more atoms from the halogen group of elements. As mentioned in Get Focused, chlorofluorocarbons are an excellent example of an organic halide because the class contains both chlorine and fluorine.

organic halide: an organic compound in which one or more of the hydrogen atoms has been replaced by halogen atoms

Vinyl chloride is another petrochemical example of an organic halide. As these examples show, an organic halide's name communicates the halogen(s) present in the substance. Later in this lesson you will learn how to apply the systematic naming system to organic halides.



Try This

Refrigeration

Halogen atoms are added to hydrocarbons to produce a compound with unique properties. Consider the following molecules:

	Methane	CFC Molecule
Chemical Formula	CH ₄	CF ₂ Cl ₂
Boiling Point (°C)	-161	-29.8

TR 1. Can you identify a reason for the difference in boiling points between these two molecules?

TR 2. In a refrigeration system, refrigerants are compressed into their liquid form and allowed to vapourize. Explain how the vapourization of either of the substances shown in the table would enable them to act as refrigerants.

Save your response in your course folder, and submit a copy to your teacher.



Read

Read page 417 in the textbook to learn the effect that adding halogens to a hydrocarbon can have. Pay careful attention to the last paragraph and “Table 1” on page 417 to learn how to apply the systematic naming process to organic halides.

Work through “Sample problem 10.1,” “Communication example 1,” and “Communication example 2” on page 418 in the textbook.

Earlier in this lesson you considered the CFC molecule CF_2Cl_2 . What is the systematic name for this molecule? Is it dichlorodifluoromethane or difluorodichloromethane—which halogen do you list first?

IUPAC rules state that when more than one type of halogen atom appears in a molecule's structure, the halogen prefixes are to be listed in alphabetical order. Therefore, the systematic name for CF_2Cl_2 is dichlorodifluoromethane.



Self-Check

SC 1. Complete “Practice” questions 1–5 on pages 418–419 in the textbook.

SC 2. Write the systematic names for the organic halides listed in “Practice” questions 4.b., c., and d., and 5.a., b., and d. on pages 418–419 in the textbook.

Check your work with the answer in the appendix.



Reflect and Connect

DDT (dichlorodiphenyltrichloroethane, a pesticide), Teflon (polytetrafluoroethylene, the non-stick coating used in cookware), and PVC (polyvinyl chloride, a type of plastic) are other organic halides. Chemical technologies like these have been very important in the development of your society and to your standard of living. However, there are also concerns related to the use of organic halides.

RC 1. Use the Internet to research organic halides and possible concerns related to their use. Why is there concern about exposure to organic halides that contain chlorine (also known as organochlorides)? To refine your search, try combining the common names of the chemical compounds listed in the paragraph above with other search terms.

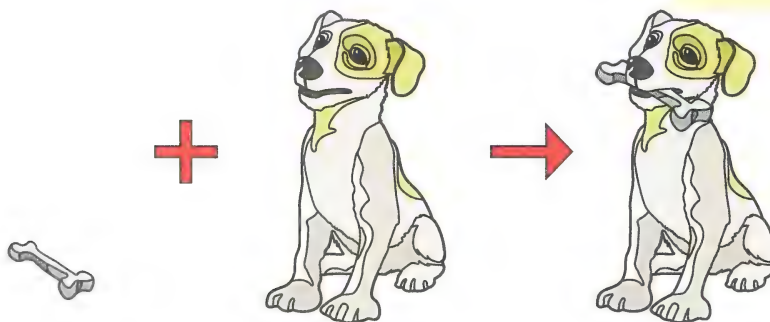
Save relevant information that you collect in your course folder. You will revisit this information later in Module 6.



Read

You might recall from previous science courses that chemical reactions can be classified. You will also recall that certain reaction types tend to happen with certain reactants. A multiple bond between carbon atoms, like those found in alkenes and alkynes, can participate in a type of reaction called an **addition reaction**.

addition reaction: a type of organic reaction involving an unsaturated hydrocarbon and a small molecule, usually hydrogen or a halogen, that increases the saturation of the hydrocarbon

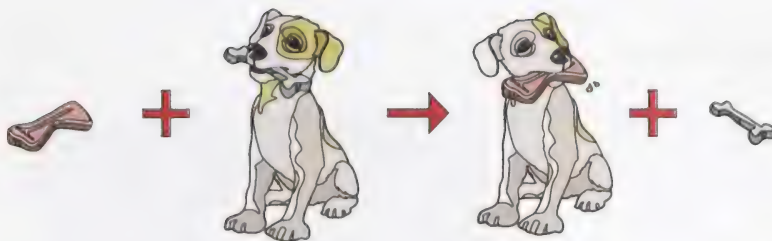


Read pages 419–421 in the textbook to learn how addition reactions can be used to produce organic halides.

Early in this lesson you were asked to consider how you could use a hydrocarbon molecule to create a hydrocarbon derivative and to describe the changes that needed to occur to transform the molecule into the derivative.

If you thought this change required substituting a hydrogen atom for a chlorine atom, you were well on your way to understanding **substitution reactions**, another reaction type used to make organic halides.

substitution reaction: a type of organic reaction involving breaking a carbon-hydrogen bond and replacing the hydrogen atom with another atom or group of atoms



Read pages 421–423 in the textbook to learn more about substitution reactions.



Self-Check

SC 3. Complete “Practice” questions 6–11 on page 422–423 in the textbook.

Check your work with the answer in the appendix.



Watch and Listen

What does it look like when an alkene reacts and undergoes an addition reaction? Go to the course multimedia DVD, and view the video “Double Bonds” to find out. As you watch the video, carefully observe changes that occur to the substances involved.

Use the results of the test performed at the end of the video to answer Try This questions 3–6.



Try This

Addition Reactions

TR 3. Prepare a data table for the tests performed during the investigation “Double Bonds.”

TR 4. Write the balanced chemical equation for the reaction between cyclohexene and bromine.

TR 5. Which substance, corn oil or octane, contains double bonds? Use the evidence from the investigation to support your answer.

TR 6. Fats that contain double bonds are often called unsaturated fats. A common test to determine the extent of the unsaturation is to perform a titration using the halogen iodine. It is observed that a 1:1 mole ratio exists between the moles of iodine that will react to the moles of double bonds in the fat. Explain why such a relationship is observed.

Save your responses in your course folder, and submit a copy to your teacher.



Reflect on the Big Picture

The effects of a technology are often realized some time after the technology is put into use. In this lesson you completed a Reflect and Connect activity in which you began to record some issues related to the use of organic halide compounds.

You have learned that organic halides are often used as solvents, often in chemical processes. A major concern is their toxicity and lack of ability to biodegrade. To respond to some of these issues, the chemical industry is taking steps to reduce possible environmental impacts.

Green chemistry describes principles that should be considered when designing industrial processes and even when using chemicals in laboratories or at home. A list of these principles appears in the Unit C Conclusion.

Consider the following two principles of green chemistry:

- Design safer chemicals and by-products—design chemical products to have little or no toxicity.
- Design chemicals and products to degrade after use—products should be able to degrade to harmless substances and should not accumulate in the environment.

Retrieve your copy of the Module 6: Lesson 1 Assignment that you saved to your computer in Lesson 1. Look at how you organized the chemical structures for the compounds shown in “Figure 2” on page 413 of the textbook. Did you group the three organic halides together?

RBP 1. Review the diagrams of the petrochemicals from the Lesson 1 Assignment, and list the three organic halides. Use the Internet to research each of the three organic halide petrochemicals you listed. Consider the following questions:

- How is this substance used?
- Is this substance considered a toxic substance?
- Is this substance biodegradable?

Summarize the results of your research in a brief table. Save a copy of your response in your course folder.



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In recent years there has been much debate about the effects of chlorine use on the environment. In Module 3 you learned that chlorine is a strong oxidizing agent, meaning that it can readily react with many substances, including organic compounds. These reactions are used to disinfect water, cause bleaching, and to make petrochemicals resulting in plastics. Many people are concerned that chlorine introduced in organic halides can become involved in other chemical change, including reactions within biological systems that could be harmful.

In another example, the burning of polyvinyl chloride (PVC plastics) can produce a number of compounds including the toxic, chlorine-containing compound, dioxin. Given such possibilities, some think that chlorine use by chemical and other industries should be banned. An Internet search will produce much more information about this debate from the scientific community and from other perspectives.



Lesson Summary

It might surprise you to know that one of the foundations of Alberta's petrochemical industry was chlorine. One of the main reasons that Dow Chemical chose to establish a petrochemical facility in Fort Saskatchewan was the location's proximity to the underground mineral deposits containing NaCl. The chlorine produced at the Fort Saskatchewan facility was used by another plant at the same facility to produce the organic halides ethylene dichloride, vinyl chloride, and polyvinyl chloride.

In Module 3 you completed an electrolysis of aqueous sodium chloride, which produced chlorine gas as a product. You may wish to revisit the Module 3 investigation and "The Chlor-Alkali Process" on page 648 in the textbook.

In Lesson 2 you considered the following questions:

- What are organic halides?
- In what reactions are organic halides involved?

Organic halides are an important class of organic compound and are used in a variety of important technological applications. It will not surprise you that, because of this importance, large quantities of these substances have been produced in petrochemical plants in Alberta and in other parts of the world. Addition and substitution reactions are the two reaction types currently used to produce organic halides.

Organic halides are also at the centre of some controversy. Plans to rethink how chemicals are made and used may help address concerns.

Lesson Glossary

addition reaction: a type of organic reaction involving an unsaturated hydrocarbon and a small molecule, usually hydrogen or a halogen, that increases the saturation of the hydrocarbon

chlorofluorocarbons (CFCs): a group of organic compounds composed of carbon, hydrogen, chlorine, and fluorine

functional group: a characteristic arrangement of atoms or bonds within a molecule that determines the most important chemical and physical properties of a class of compounds

hydrocarbon derivative: a molecular compound of carbon, at least one other element, and, usually, hydrogen

organic halide: an organic compound in which one or more of the hydrogen atoms has been replaced by halogen atoms

substitution reaction: a type of organic reaction involving breaking a carbon-hydrogen bond and replacing the hydrogen atom with another atom or group of atoms

Module 6—Petrochemicals

Lesson 3—Alcohols



Get Focused

You may have heard of biofuels being used to fuel automobiles. Biofuel, or gasohol as it is called in many countries, is a mixture of gasoline and ethanol. In Canada you can purchase automobile fuel with up to ten percent ethanol. In countries like Brazil, the ethanol percentage is significantly higher.

Blending petroleum and ethanol is somewhat like diluting the petroleum component of gasoline while ensuring the energy content of the fuel. In Brazil, where all petroleum is imported but there are substantial resources to make ethanol, blending allows the country to make the greatest use of its resources.

Like other petrochemicals, ethanol can be produced from the hydrocarbon ethene using an addition reaction. Ethanol can also be produced by fermenting corn and other crops. Is producing ethanol by fermentation a more preferred option than producing ethanol by chemical synthesis?

In Lesson 3 you will learn about the different methods of producing ethanol and the properties of similar molecules called alcohols.

Consider the following questions as you complete Lesson 3:

- What are alcohols?
- Are alcohols being produced and used in a responsible way?



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Module 6: Lesson 3 Assignment

You will be directed to go to the Assignment Booklet to complete the Module 6: Lesson 3 Assignment later in this lesson.

You must decide what to do with the questions that are not marked by the teacher.

Remember that these questions provide you with the practice and feedback that you need to successfully complete this course. You should respond to all the questions and place those answers in your course folder.



Read

Alcohols are another type of hydrocarbon derivative and a commonly produced petrochemical. Read pages 425–426 in the textbook to learn more about alcohols.

alcohol: an organic compound containing one or more hydroxyl groups as the functional group

Two alcohols, methanol and ethanol, were discussed in the section you just read. What is the difference between these two substances? How do their names convey information about the chemical structures of each compound?

Read pages 427–431 in the textbook for more information on how alcohols are named. Work through the “Sample problems” and “Communication examples” provided on these pages to practise your skills in naming and writing chemical structures for alcohols.



Self-Check

SC 1. Complete “Practice” question 4 on page 426 and “Practice” questions 5–17 on pages 430–431 of the textbook.

Check your work with the answer in the appendix.



Read

Alcohols like methanol and ethanol can be reactants in chemical processes that produce other petrochemicals. Read “Elimination Reactions” on pages 431–433 in the textbook.



Self-Check

SC 2. Complete “Practice” questions 18–20 on page 433 of the textbook.

Check your work with the answer in the appendix.



Module 6: Lesson 3 Assignment

Open the Assignment Booklet. Complete “Part 1” of “Module 6: Lesson 3 Assignment.”



Reflect and Connect

Ethanol is being championed around the world as a great fuel additive for blending with gasoline. One day, ethanol might even be a substitute for gasoline. Ethanol is environmentally sound because it can be made through yeast fermentation from renewable resources such as corn, sugar cane, and switch grass.

It may seem ideal to use a renewable resource to make ethanol; however, there are concerns about how much land the process requires. Some people argue that the land used to grow the plants for ethanol production could be used to grow food for the world's hungry.

A greener option for ethanol production may be to use waste products. Research is being done to find a way to use agricultural waste (such as straw) or pulp and paper waste (such as wood chips) for ethanol production. This would resolve the land-use concern and would make use of an otherwise unused waste product.



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Try This

Cellulosic Ethanol

TR 1. Take a deeper look into the production of ethanol as a biofuel. Open “Web Activity: Web Quest—Cellulosic Ethanol.” Read the instructions and discuss which parts of the project you will be responsible for with your teacher. Complete the requirements for the activity as described in the document. Go to the website for the textbook if you need live links to the websites and documents listed. Information to help you find the activity on the website is contained in the print version linked into this paragraph.

When you have completed the activity, contact your teacher for further instructions on submitting and/or sharing your presentation. Save a copy of your work and presentation in your course folder.



Module 6: Lesson 3 Assignment

Open the Assignment Booklet. Complete “Part 2” of “Module 6: Lesson 3 Assignment.” To complete this part you will need to review the information collected for your presentation in TR 1. You may also be able to review the presentations of other students by using the discussion area for your class.



Lesson Summary

In Lesson 3 you considered the following questions:

- What are alcohols?
- Are alcohols being produced and used in a responsible way?

Alcohols are a group of organic compounds containing a hydroxyl group. Alcohols can be produced by chemical synthesis or, as is the case in ethanol production, by plant fermentation. Alcohols are a very useful group of organic compounds due to their chemical and physical properties. For example, alcohols are often used as solvents in chemical processes, in antifreezes, and as a reactant in elimination and other reactions with organic compounds.

Your work in this lesson, and later in this module, will show you that alcohols are a very important class of organic compounds, not only because of their ease of combustion and high energy content, but because of their use in synthetic reactions. In the next lesson you will learn about esterification reactions, another type of organic reaction in which an alcohol is a reactant.

Many countries are looking into ethanol as a fuel additive or even as a fuel alternative, because ethanol is a renewable resource. The use of ethanol as a biofuel has sparked a great deal of interest and concern. In Lesson 3 you considered many of the perspectives associated with this issue.

Lesson Glossary

alcohol: an organic compound containing one or more hydroxyl groups as the functional group

Module 6—Petrochemicals

Lesson 4—Carboxylic Acids and Esters



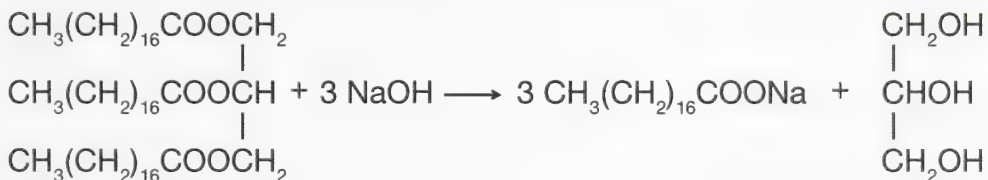
Get Focused

In Unit A you learned about biodiesel, an alternative automobile fuel made from waste cooking oil. Finding a use for waste oils and other compounds that are waste products of other processes makes good sense. It is not surprising that finding a use for “waste” materials is consistent with the principles of green chemistry, since this practice does not allow for substances to accumulate without a purpose.

Examine the biodiesel reaction shown below. Do you recognize a familiar chemical structure, one that would belong to a group of molecules introduced in a previous lesson in this module?



Biodiesel Reaction



waste oil

a typical sodium salt
found in soap

glycerol

You may have noticed that an alcohol is a product of the reaction. In Lesson 3 you learned about alcohols—a type of organic compound that contains an oxygen atom in its functional group. If you look closely at the reactant and other products of the reaction, you will notice that there are two other types of organic compounds containing oxygen. These two classes of molecules will be the focus of this lesson. In Lesson 4 you will learn about carboxylic acids and esters.

Consider the following questions as you complete Lesson 4:

- What are carboxylic acids and esters?
- How are carboxylic acids and esters involved in the petrochemical industry?



Module 6: Lesson 4 Assignment

You will be directed to go to the Assignment Booklet to complete the Module 6: Lesson 4 Assignment later in this lesson.

You must decide what to do with the questions that are not marked by the teacher.

Remember that these questions provide you with the practice and feedback that you need to successfully complete this course. You should respond to all the questions and place those answers in your course folder.

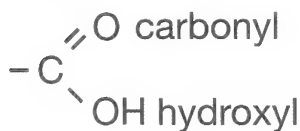


Explore

The second class of organic molecules that contains oxygen atoms is the **carboxylic acids** family. Read pages 436–437 in the textbook to learn more about carboxylic acids.

carboxylic acids: a family of organic compounds characterized by the carboxyl group (-COOH)

Carboxylic acids always contain the carboxyl functional group, which is illustrated below. Work through “Sample problem 10.5” and “Communication example 1” on page 438 in the textbook.



You might note that in the reaction for biodiesel shown in Get Focused, the first product—the carboxylic acid—is not complete; it is deficient a hydrogen atom. The hydrogen in question is part of the hydroxyl group, within the carboxyl group. In Unit D you will learn more about the reactions and acidity of carboxylic acids. You will also learn how a carboxylic acid can be correctly represented in the form shown in the biodiesel equation.



Self-Check

SC 1. Complete “Practice” questions 1–2 on page 438 in the textbook to practise naming and drawing chemical structures for carboxylic acids.

Check your work with the answer in the appendix.

**Read**

In Module 6 you have studied many kinds of organic reactions including substitution, fermentation, cracking, addition, and elimination. Another major reaction of carboxylic acids is an **esterification reaction**. Read pages 438–440 in the textbook to learn about this type of chemical reaction and its product—**esters**.

Work through “Sample problem 10.6,” “Sample problem 10.7,” and Communication example 2” on page 440 in the textbook.

esterification reaction: a chemical reaction in which a carboxylic acid and an alcohol combine to produce an ester and water

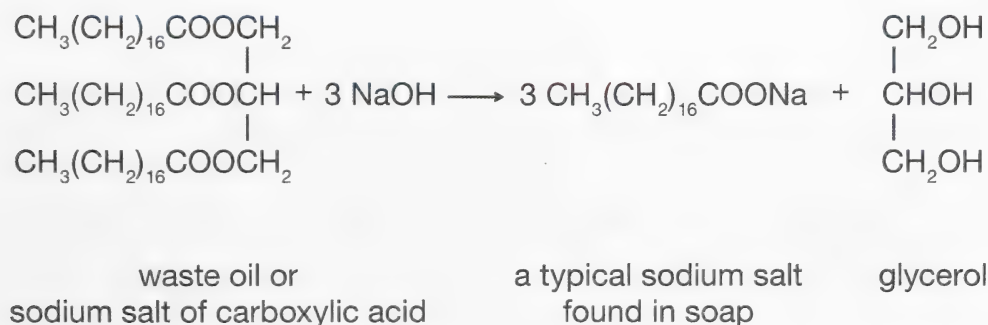
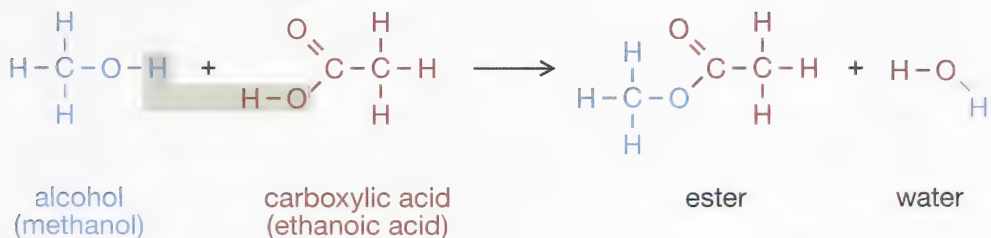
esters: a family of organic compounds characterized by the ester functional group ($-\text{COO}-$)

**Watch and Listen**

Go to the course multimedia DVD, and listen to the audio clip “Naming and Preparing Esters” to better your understanding of esters. References made to “the margin” are references to the margins of the textbook. You may also wish to save a copy of “Naming and Preparing Esters—Print Copy” (also available on the course multimedia DVD) in your course folder.

**Reflect and Connect**

RC 1. Compare the two processes shown in the reactions below. Identify similarities and differences between the two reactions.



You may have noticed that these two reactions involve the same reactants and products but are each other's reverse—one creates an ester and the other breaks down an ester.

Interestingly, esters are used in making soap. Animal fats and vegetable oils are esters and are a key ingredient in making soap. When esters are combined with a strong base, sodium hydroxide for example, and heated, the reaction creates a salt of a carboxylic acid (the soap), and glycerol (propane-1,2,3-triol).



Self-Check

SC 2. Complete “Practice” questions 4–6 on page 441 in the textbook.

Check your work with the answer in the appendix.



Module 6: Lesson 4 Lab—Synthesizing Esters

Purpose

You will prepare a synthetic, organic compound—an ester.



Open the Assignment Booklet, and then, open the handout “Making Esters.” Use the handout to complete “Pre-Lab” in “Module 6: Lesson 4 Assignment.”

Materials

- tap water
- beaker
- 25 mm × 250 mm test tubes (or larger) (one for each reaction)
- three 10-mL graduated cylinders
- test-tube clamp (or utility clamp)
- reflux apparatus (one-hole stopper with inserted glass tubing)
- alcohols and carboxylic acids made available by your teacher
- dropper bottle containing concentrated sulfuric acid (handled only by your teacher)
- weighing boat
- lab stand
- hot plate
- thermometer
- thermometer clamp
- laboratory tongs
- laboratory scoop
- electronic balance
- a vial of salicylic acid
- evaporating dish (one per reaction)
- test-tube rack
- tray or large beaker containing ice

If you have access to the materials listed, you may be able to perform this investigation.



If you do not have access to these materials and a supervised laboratory, or if you would like to see the lab performed before you attempt it, go to the course multimedia DVD and view the virtual investigation “Lesson 4 Lab: Synthesizing Esters.” If you will not be completing the lab yourself, remember to record data and observations as you view the presentation.

Procedure

Step 1: Assemble a water bath by placing a 250-mL beaker, half-filled with tap water, onto the hot plate. Place the water bath close to the lab stand. Attach the thermometer clamp to the lab stand, and position the thermometer inside the clamp in such a way that it measures the temperature of the water inside the water bath. Attach the test-tube clamp to the lab stand.

Step 2: Transfer approximately 4 mL of the carboxylic acid you have chosen and approximately 5 mL of the alcohol you have selected into separate graduated cylinders. If you use salicylic acid, measure approximately 2 g of the salicylic acid crystals into a weighing boat.

Step 3: Transfer the contents from the graduated cylinders to the test tube. Fasten the test tube to the test-tube clamp attached to the lab stand in such a way that the reactants in the test tube are below the surface of the water bath.

Step 4: Use a clean graduated cylinder to measure 2 mL of concentrated sulphuric acid. Add this to the contents of the test tube.

Step 5: Attach the reflux apparatus to the test tube. Turn on the hot plate, and begin heating the water bath. Monitor the temperature of the water bath during the experiment to maintain the temperature of the water bath between 70 °C and 80 °C. Allow the contents of the test tube to heat for 15 minutes.

Step 6: Remove the test tube from the water bath, and allow the contents to cool for five minutes; then place the test tube into a second water bath containing cold or ice water for five minutes.

Step 7: Pour the cooled contents into an evaporating dish. Gently waft the vapour from the dish containing the synthesized ester toward you. Record the odour detected in the appropriate place in your table.

Step 8: Repeat Steps 2 to 7 for your two other esters.

Step 9: Follow your teacher’s instructions regarding the disposal of liquid waste. Be careful not to spill or splash the esters—these mixtures contain sulfuric acid.

Step 10: Disassemble, wash (if needed), and return the equipment to its appropriate place.



Module 6: Lesson 4 Assignment

If you have not already done so, open the Assignment Booklet. Complete the remainder of “Module 6: Lesson 4 Assignment.”

Atom Economy—One Way to Green Chemical Processes

A chemical process’ **atom economy** is important when trying to green the chemical industry. Atom economy is a percentage of the molecular mass of the product and the reactants used in creating the product. The equation to calculate atom economy is as follows:

atom economy: the percentage of material present in reactants that ends up in the desired product for a chemical process

$$\text{Atom Economy} = \frac{\text{Molecular Mass of Product}}{\text{Molecular Mass of Reactants}} \times 100$$

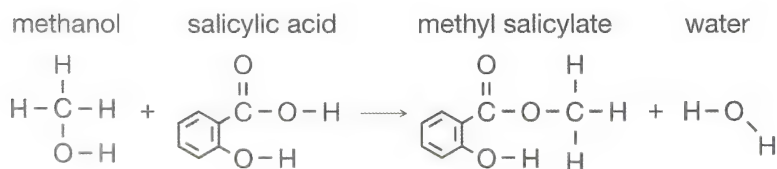
In the calculation for atom economy, the reaction’s waste or by-products are not directly counted, but are significant. What is the waste product of an esterification reaction? How does the molecular mass of the waste product of an esterification compare to the molecular mass of other organic reactions; for example, a substitution reaction? Does the difference in the molecular mass of the by-products of these two reactions result in a significant difference in the atom economy when these two types of reactions are compared?



Go to the course multimedia DVD, and consider “Worked Example,” which calculates the atom economy for the production of methyl salicylate.

Atom Economy Example Problem

Reaction



Molecular Mass

C 1×12.01 g/molH 4×1.01 g/molO 1×16.00 g/mol

Total = 32.05 g/mol

H 2×1.01 g/molO 1×16.00 g/mol

Total = 18.02 g/mol

C 7×12.01 g/molH 6×1.01 g/molO 3×16.00 g/mol

Total = 138.13 g/mol

C 8×12.01 g/molH 8×1.01 g/molO 3×16.00 g/mol

Total = 152.16 g/mol

$$\begin{aligned}
 \text{Atom Economy} &= \frac{\text{Molecular Mass of Product}}{\text{Molecular Mass of Reactants}} \times 100 \\
 &= \frac{152.16 \text{ g/mol}}{(32.05 \text{ g/mol} + 138.13 \text{ g/mol})} \times 100 \\
 &= \frac{152.16 \text{ g/mol}}{170.18 \text{ g/mol}} \times 100 \\
 &= 89.41\%
 \end{aligned}$$



Self-Check

SC 3. Calculate the atom economy for the esters made using the alcohols and carboxylic acids shown in the following table:

Reaction	Alcohol	Carboxylic Acid	Ester
1	ethanol	ethanoic acid	ethyl ethanoate
2	propan-1-ol	methanoic acid	propyl methanoate

Check your work with the answer in the appendix.



Reflect on the Big Picture

Designing chemical reactions that consider atom economy can be very helpful when attempting to improve efficiency and minimize the chemical industry's effect on the environment.

When greater proportions of a chemical reaction's reactants end up in the product, fewer waste or by-products are made. In the calculations you just performed, the only by-product is a water molecule, which is both small and non-toxic. In general, complex syntheses involving multiple reactions have lower atom economies and lower overall yields.



Try This

Develop an answer to one of the following questions. When possible, use examples and relevant calculations to support your answers.

TR 1. How does the molecular mass of the waste product of an esterification compare to the molecular mass of other organic reactions; for example, a substitution reaction?

TR 2. Does the difference in the molecular mass of the by-products of the two reactions in TR 1 result in a significant difference in the atom economy when these two types of reactions are compared?

TR 3. How could a chemical process be designed to maximize atom economy?

TR 4. How would the atom economy of a process that requires many reactions compare to a process that is completed in one reaction?



Post your answer to the discussion area for your class. Read the responses of at least two other students. Do their responses show a correct understanding of atom economy? Share your constructive comments with your classmates. Revise your response, if necessary, and submit a copy to your teacher.



Lesson Summary

In this lesson you learned about carboxylic acids and esters, two classes of organic compounds.

In Lesson 4 you considered the following questions:

- What are carboxylic acids and esters?
- How are carboxylic acids and esters involved in the petrochemical industry?

During this lesson you synthesized an ester in a laboratory investigation, and you calculated the atom economy of an esterification reaction. Many chemical industries synthesize organic compounds such as carboxylic acids and esters.

Chemical industries consider atom economy and other principles of green chemistry when developing their processes to improve their scientific and business practices and to reduce their environmental impact. In Lesson 6 you will apply your knowledge from this lesson to investigate polymers—both natural and synthetic—that are produced by esterification reactions.

Lesson Glossary

atom economy: the percentage of material present in reactants that ends up in the desired product for a chemical process

carboxylic acids: a family of organic compounds characterized by the carboxyl group ($-\text{COOH}$)

esterification reaction: a chemical reaction in which a carboxylic acid and an alcohol combine to produce an ester and water

esters: a family of organic compounds characterized by the ester functional group ($-\text{COO}-$)

Module 6—Petrochemicals

Lesson 5—Addition Polymers



Get Focused

In Lesson 4 you learned that an esterification reaction involves a synthesis, or joining, of molecules. Many of the petrochemical industry's products involve synthesis reactions—the most important example of this is plastics. In Lessons 5 and 6 you will learn how addition and condensation reactions can be used to synthesize different types of plastics.

Although many people recycle the plastics they use, estimates suggest that only five percent of the plastic created (as an off-shoot of the petrochemical industry) is recycled. This low recycling rate is due, in part, to the lack of incentive to get people to recycle plastics and the lack of a market for recycled plastics.

Not all plastics are recyclable. You can identify whether an item is recyclable by looking for the recycling code on the product. The number within the code indicates the composition of the plastic. Recyclable plastics include polyethylene, polyvinyl chloride, polypropylene, and polystyrene. You will explore these plastics in this lesson.



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You may recall examining the chemical structures of these compounds in Lesson 1 of this module. What aspect of the chemistry of these substances allows them to be made into plastics?

Consider the following questions as you complete Lesson 5:

- What is the process used to make plastic?
- What properties must molecules have if they are to be used in making plastic?



Module 6: Lesson 5 Assignment

There is no assignment for this lesson. However, you will be asked to submit samples of your work to your teacher where instructed.

You must decide what to do with the questions that are not marked by the teacher.

Remember that these questions provide you with the practice and feedback that you need to successfully complete this course. You should respond to all the questions and place those answers in your course folder.



Explore

There is plastic in almost everything around you. Plastics are **polymers**—macromolecules created by linking many smaller molecules. The small molecules that make up a polymer are called **monomers**. The process of joining monomers together is called **polymerization**.

polymer: a large molecule made by linking together many smaller molecules called monomers

monomer: a small molecule that links with many other similar molecules in an addition or condensation reaction to create a polymer

polymerization: the process of forming polymers from monomers through addition or condensation reactions



Self-Check

In Lesson 1 of this module you organized diagrams of the chemical structures for different petrochemical compounds based on structural similarities. In this activity you will review those diagrams to learn more about polymers. Retrieve those diagrams now.

Step 1: Sort through the diagrams and find the molecules with the term “poly” in their name.

Step 2: Sort through the remaining diagrams. For each polymer identified in Step 1, find the card that contains the corresponding monomer.

SC 1. Prepare a chart with two columns. The left-hand column should be titled “Polymer” and the right-hand column should be titled “Corresponding Monomer.” Complete the chart based on your work in Steps 1 and 2.

SC 2. Identify the similarity between all the monomers listed in your table. Suggest a mechanism by which the monomers can be joined to become a polymer.

SC 3. Sort through the remaining cards and identify any other substances that could be monomers. Justify why you chose these molecules.

Check your work with the answer in the appendix.

As you have seen from this Self-Check activity, there are many kinds of polymers. Polymers made from petrochemicals are often called plastics because they have the ability to be moulded. You may be familiar with other kinds of polymers, like polyester, which will be discussed in Lesson 6. As you may have guessed, polyesters have a different chemistry than addition polymers, the topic of this lesson.



Read

Read pages 445–447 in the textbook to learn more about addition reactions—one of the mechanisms by which addition polymers can be formed.



Try This

Teflon: Healthy or Hazardous?

When Teflon was first used as a non-stick agent in cookware, it was considered revolutionary. Teflon was an exciting find for people watching their weight or cholesterol, because it allowed food to be cooked with little or no oil. Is there more to the Teflon story? Is Teflon toxic?



TR 1. Go to the course multimedia DVD, and open “Web Activity: Web Quest—Teflon: Healthy or Hazardous,” referenced on page 448 in the textbook. Read the instructions and

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discuss which parts of the project you will be responsible for with your teacher. Complete the activity. Go to the website for the textbook if you need live links to the websites and documents referenced. Information to help you find the activity on the website is available in the print version linked into this paragraph.

When you have completed the activity, contact your teacher for further instructions on submitting and/or sharing your presentation.

Save a copy of your work and your presentation in your course folder.



Self-Check

SC 4. Complete “Practice” questions 1–8 on page 448 of the textbook.

Check your work with the answer in the appendix.



Discuss



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Plastics form part of almost every product you use, and they have added convenience to many areas of your life. Cars, computers, cell phones, water bottles, and baby bottles all contain plastic. Even most of your food and toiletries come in plastic containers. As a result, even with recycling programs, many landfills are full of plastic.

D 1. Think about everything you have learned so far in Module 6. Do you think the way society uses plastics is a good use of the natural resource from which plastics originate? Write a few paragraphs to provide your opinion on this question.

Post your response to the discussion area for your class. Read the responses of at least two other students. Identify similarities and differences in the responses you read. Save a copy of your opinion and the similarities and differences you identified in your course folder.



Reflect on the Big Picture

Plastics for food storage—often made of polypropylene and polystyrene—are tested for safety. Tests have shown that polypropylene can be heated to high temperatures without any leeching of monomers into the food or beverage the container holds. Heating or exposing polystyrene to alcohol or oil, however, will cause a breakdown of the polymer, which then leeches some styrene monomers into the food or beverage.

The plastics industry, a subset of the petrochemical industry, is addressing safety and environmental concerns in several ways. For example, the recycle codes on plastic products provide recycling information and tell consumers how to safely use each product. The industry is also adding a variety of molecules to increase plastic's ability to biodegrade. In Lesson 6 you will learn about bioplastics, which can totally degrade.



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Lesson Summary

In Lesson 5 you considered the following questions:

- What is the process used to make plastic?
- What properties must molecules have if they are to be used in making plastic?

Polymerization is the process of creating large molecules by linking many smaller molecules together. One type of polymerization is addition polymerization. This process involves linking many alkene molecules to form polymers. Polymers are many monomers linked together. Synthetic polymers such as polyethylene, polyvinyl chloride, polypropylene, and polystyrene are used to create a variety of plastic products.

Lesson Glossary

monomer: a small molecule that links with many other similar molecules in an addition or condensation reaction to create a polymer

polymer: a large molecule made by linking together many smaller molecules called monomers

polymerization: the process of forming polymers from monomers through addition or condensation reactions

Module 6—Petrochemicals

Lesson 6—Condensation Polymers



Get Focused

You now know that polymers are important substances that have many uses. Addition polymers, which you studied in Lesson 5, are formed when monomers with double bonds join to make much larger molecules. Have you studied other reaction types that can also connect smaller molecules to make larger molecules?

In Lesson 4 you learned about esterification reactions, a type of condensation reaction in which a water molecule is formed when alcohol and organic acid molecules are joined together. Could this reaction type be used to make a polymer?



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In this lesson you will learn how condensation polymerization reactions can be used to produce both synthetic (such as plastics) and natural polymers including proteins, lipids, and carbohydrates. You will compare many natural and synthetic polymers and their respective properties.

Consider the following questions as you complete Lesson 6:

- How do natural and synthetic polymers compare?
- What are other reaction mechanisms by which polymers can be made?

You will also take another look at how the petrochemical industry, and its offshoot industries like the plastics industry, are attempting to green their practices.



Module 6: Lesson 6 Assignment

You will be directed to go to the Assignment Booklet to complete the Module 6: Lesson 6 Assignment later in this lesson.

You must decide what to do with the questions that are not marked by the teacher.

Remember that these questions provide you with the practice and feedback that you need to successfully complete this course. You should respond to all the questions and place those answers in your course folder.



Explore



Try This

The Structure of a Polyester

You have probably heard of polyester. Many fabrics are made from this polymer, which is formed by linking monomers with the ester functional group. In this activity you will learn more about the structure of a polyester.

Retrieve the diagrams of the chemical structures of the petrochemical compounds you started using in Lesson 1. Find the diagrams with the chemical structures for the following molecules:

- ethanol
- isopropanol
- ethylene glycol
- acetic acid
- adipic acid



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TR 1. Using structural formulas, write balanced chemical equations to describe the six esters that can be formed using these components.

TR 2. Recall that a polymer is a long molecule often containing thousands of monomers. Which one of the esters you wrote in TR 1 has the potential to continue to react to form a long molecule?

TR 3. Write the balanced chemical equation for the formation of a polymer using the monomers identified in TR 2. Ensure that the polymer you show in your answer has at least two of each of the monomer molecules.

Save your work in your course folder, and submit a copy of your response to TR 3 to your teacher.



Read

In the Try This activity you just completed, you identified that a polymerization reaction can involve a reaction other than an addition reaction.

Condensation polymers and **condensation polymerization** reactions are very common in industry and in biological systems. Read pages 449–452 in the textbook to learn more about condensation polymers and polymerization reactions.

condensation polymerization: a reaction in which a water molecule is produced when two monomers are chemically joined



Self-Check

SC 1. Complete “Practice” questions 9–11 on page 451 and questions 12–14 on page 452 of the textbook.

Check your work with the answer in the appendix.



Discuss

Cloth or disposable diapers? This might be a decision that you have to make in the future as you become a parent. Read through “Explore an issue” on page 455 in the textbook.

D 1. In a document, indicate whether you will support cloth diapers or disposable diapers, and list supporting facts. Next, include some insight into making your product choice more green. What materials or processes could be used to make your choice of diaper more environmentally sound?

Post your response in the discussion area for your class, and respond to the opinions of at least two students who do not share your viewpoint. Save your work in your course folder.



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Going Beyond

Proteins—key components of plants and animals—are another type of natural polymer. Proteins are formed when many amino acids are joined together using an **amide functional group** between monomers.

proteins: natural polymers of amino acids forming the basic material of living things

amide functional group: a group of atoms composed by connecting a carboxyl group to an amine group

nylon: a synthetic condensation polymer



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Nylon is a synthetic polymer that is also created using amide groups between monomers. Nylon was created as a substitute for silk and is very strong. Nylon is used to create ropes, parachutes, and as you well know, many of the clothes you wear.



Read

Read pages 452–454 in the textbook to learn more about proteins and nylon.



Read



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Carbohydrates are an important polymer in biological systems. Starch, cellulose, and glycogen are all polymers of sugar molecules joined by a condensation reaction.

Read pages 456–458 in the textbook to learn more about carbohydrates and the synthetic polymer cellulose acetate.



Self-Check

SC 2. Complete “Practice” questions 18–23 on page 458 in the textbook.

Check your work with the answer in the appendix.



Self-Check

SC 3. Complete “Section 10.5” questions 1, 2, and 4–14 on page 460 in the textbook.

Check your work with the answer in the appendix.



Reflect on the Big Picture



Earlier in this module you considered concerns regarding the use of plastic shopping bags. Plastics have received a negative reputation for polluting the environment and for taking considerable time to degrade. These concerns are driving an increased interest in bioplastics. Bioplastics are a type of biopolymer—a natural polymer.

Bioplastics are made from polyalkanoates, a type of polymer containing ester bonds between monomers. Polyalkanoates are created by some plants and bacteria. Since these polyesters are naturally produced, they can also be broken down by bacteria and other organisms, making them biodegradable. Could bioplastics be the material of the future?

RBP 1. As a final reflection on what you learned in this module, retrieve the document in which you answered the “Starting Points” questions on page 410 in the textbook. Revise the answers you initially provided. Comment on how your answers changed as a result of what you learned in this module. Save your revised document in your course folder.



Module 6: Lesson 6 Assignment

Open the Assignment Booklet. Complete “Module 6: Lesson 6 Assignment.”



Lesson Summary

In Lesson 6 you considered the following questions:

- How do natural and synthetic polymers compare?
- What are other reaction mechanisms by which polymers can be made?

There are many examples of synthetic and natural polymers that can be produced through condensation polymerization. Specifically, you considered polyester, proteins and nylon, and carbohydrates and cellulose acetate.

You also further considered the effect of the petrochemical industry and its offshoot industries on the environment, and you took a look at bioplastics.

Lesson Glossary

amide functional group: a group of atoms composed by connecting a carboxyl group to an amine group

condensation polymerization: a reaction in which a water molecule is produced when two monomers are chemically joined

nylon: a synthetic condensation polymer

proteins: natural polymers of amino acids forming the basic material of living things

Module 6—Petrochemicals

**Module Summary**

In Module 6 you considered the following module questions:

- What kinds of chemical reactions are used to manipulate hydrocarbons in order to produce petrochemicals?
- How has the chemical industry responded to concerns about the environment?
- What are some of the processes that occur within Alberta's petrochemical industry?

You explored the petrochemical industry and the processes used to convert the hydrocarbons found in petroleum into petrochemicals. Many of the products you use every day are made from petrochemicals.

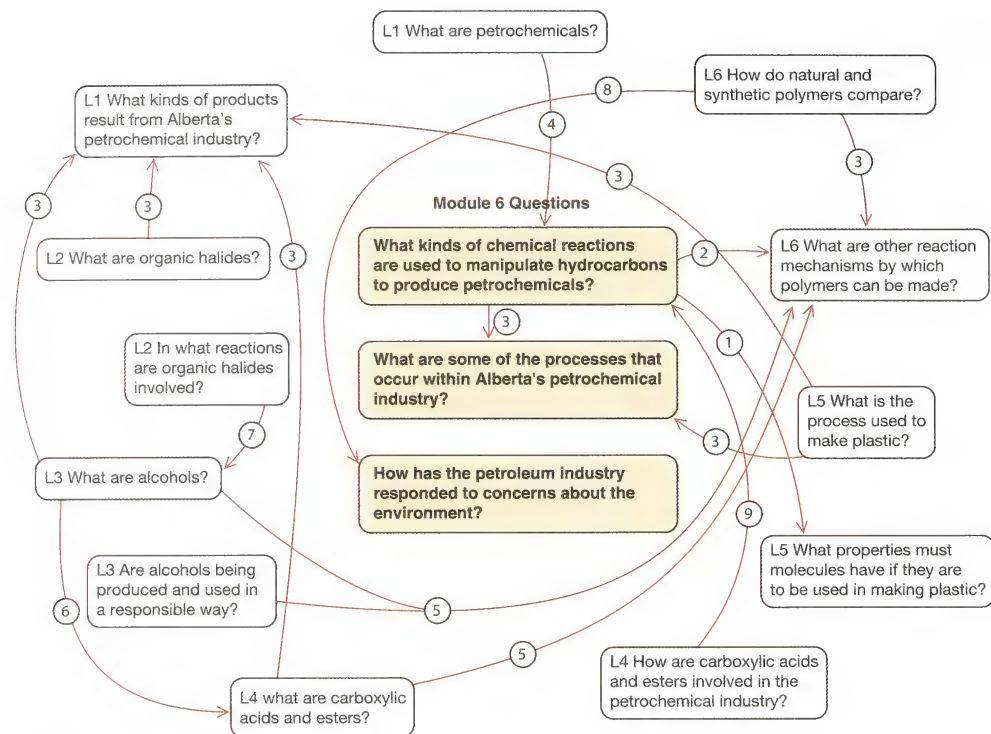
The chemical structures of hydrocarbons are extremely important to the type of petrochemical that can be made from the hydrocarbons and the reaction type that will work with them. For example, you studied polymers, which can be made by either addition reactions (from unsaturated compounds) or condensation reactions (from hydrocarbon derivatives).

You also learned that it is important to consider atom economy and toxicity of reaction by-products when designing chemical syntheses—these are important considerations if the chemical industry is to demonstrate sustainability.

Concept Map or Graphic Organizer

As you worked through Module 6, you may have added information to a concept map or graphic organizer based on the module and lesson questions listed in the Module 6 Concept Organizer. Now is a good time to review the relationships in your concept map or graphic organizer and to try to answer the module and lesson questions.

The sample Module 6 concept map shown below provides one set of possible links between the questions. Remember that this is one possible description only—there are many other correct possibilities. However, if your completed concept map or graphic organizer differs significantly from the sample, you may wish to contact your teacher or to compare your map or organizer with those of other students in your class. This will ensure that your interpretations of lesson materials and your descriptions are accurate.



Module Assessment

The Module 6 Assessment is included in the Unit C Assessment. Refer to the Unit C Assessment for details.

Module 6 Glossary

addition reaction: a type of organic reaction involving an unsaturated hydrocarbon and a small molecule, usually hydrogen or a halogen, that increases the saturation of the hydrocarbon

alcohol: an organic compound containing one or more hydroxyl groups as the functional group

amide functional group: a group of atoms composed by connecting a carboxyl group to an amine group

atom economy: the percentage of material present in reactants that ends up in the desired product for a chemical process

carboxylic acids: a family of organic compounds characterized by the carboxyl group (-COOH)

chlorofluorocarbons (CFCs): a group of organic compounds composed of carbon, hydrogen, chlorine, and fluorine

condensation polymerization: a reaction in which a water molecule is produced when two monomers are chemically joined

esterification reaction: a chemical reaction in which a carboxylic acid and an alcohol combine to produce an ester and water

esters: a family of organic compounds characterized by the ester functional group (-COO-)

functional group: a characteristic arrangement of atoms or bonds within a molecule that determines the most important chemical and physical properties of a class of compounds

hydrocarbon derivative: a molecular compound of carbon, at least one other element, and, usually, hydrogen

monomer: a small molecule that links with many other similar molecules in an addition or condensation reaction to create a polymer

nylon: a synthetic condensation polymer

organic halide: an organic compound in which one or more of the hydrogen atoms have been replaced by halogen atoms

petrochemical: a chemical made or extracted from petroleum

polymer: a large molecule made by linking together many smaller molecules called monomers

polymerization: the process of forming polymers from monomers through addition or condensation reactions

proteins: natural polymers of amino acids forming the basic material of living things

substitution reaction: a type of organic reaction involving breaking a carbon-hydrogen bond and replacing the hydrogen atom with another atom or group of atoms

Unit C Conclusion

In Unit C you learned about hydrocarbons and their derivatives. You discovered how important hydrocarbons are to society. Not only do hydrocarbons provide an energy source, but they can also be chemically manipulated to produce a variety of organic compounds.

The organic compounds produced from petroleum are called petrochemicals. Petrochemicals are used in a wide variety of products ranging from structural materials to medicines.



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You investigated the following module questions:

Module 5

- What is petroleum?
- What does Alberta's petroleum industry do?
- Where do hydrocarbons come from?
- What are hydrocarbons and what makes them such an important class of compounds?
- What are some of the processes that occur within Alberta's petroleum industry?
- What impact does the hydrocarbon industry have on Alberta's economy and environment?

Module 6

- What kinds of chemical reactions are used to manipulate hydrocarbons in order to produce petrochemicals?
- How has the chemical industry responded to concerns about the environment?
- What are some of the processes that occur within Alberta's petrochemical industry?

You also investigated the local, provincial, national, and international impacts of the petroleum industry from a variety of perspectives, and you learned about the practices to be considered when greening chemical processes.

Crucial to these changing practices is the type of materials being produced, the toxicity of the materials, and the toxicity of by-products and other waste. Efficiency of reactions must also be considered. Efficiency can be achieved by using processes that have greater atom economy and by developing processes that use less energy and have a higher percentage reaction.

You should now be able to

- identify and explain how organic compounds are a common form of matter
- describe chemical reactions of organic compounds



Self-Check



Go to the course multimedia DVD, and complete the “Unit C Diagnostic Self-Check” to review the concepts, skills, and knowledge introduced and to assess your understanding of them.

If you have trouble answering any of the questions, try one or more of the following options:

- Go to the lesson(s) indicated for each question. Once there, review the information provided and the relevant sections of the textbook.
- View the hint associated with each question.
- Look at the answer and then work backward to understand the problem and its solution.
- Ask your teacher for help.

You understand how important it is to review material in preparation for any tests your teacher may give you and in solidifying your understanding of new concepts. Completing these questions is just one part of your review. Program of Studies information is associated with each question. You may wish to use this information to identify areas in which you need to pay particular attention. You may also answer the questions that appear at the end of each chapter and unit in the textbook.

You have already reviewed your Modules 5 and 6 concept maps or graphic organizers. Now is a good time to give them another look and add any new connections or ideas to them.

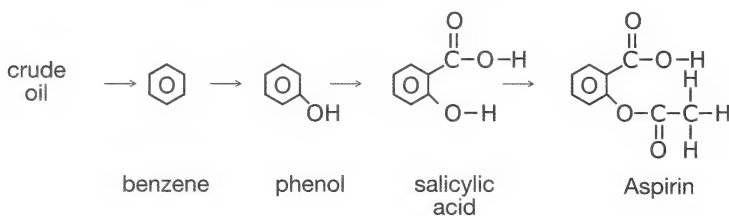


Unit Assessment

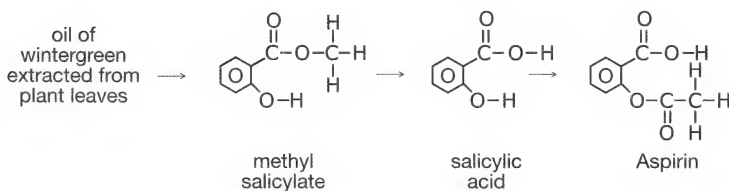
Commercial Aspirin (acetylsalicylic acid or ASA) is an ester of salicylic acid. It is one of the most commonly used drugs in the world. First Nations peoples also used salicylic acid for medicinal purposes—their sources however, such as willow bark, were natural.

Today's commercial Aspirin uses modifications like esterification to provide pain relief with fewer negative side effects. The commercial Aspirin synthesis is accomplished using benzene as a reactant. The reactions for the commercial synthesis and for an alternative method are summarized in the following diagrams:

Commercial Synthesis of Aspirin



Alternative Method for Synthesis of Aspirin



1. Describe what happens in a substitution reaction. Identify a step in the processes shown in which a substitution reaction occurs.
2. Provide the structural formula for the substance used to convert salicylic acid into Aspirin.
3. From a greening perspective, give two advantages and one disadvantage of using the alternative method for synthesizing Aspirin.

Use the scoring guide provided to plan your responses and to review your work before submitting it to your teacher.

Save a copy of your completed Unit C Assessment in your course folder, and submit a copy to your teacher.

Score	Scoring Description
5 Excellent	The student demonstrates an excellent understanding of all the components of the question and fully and correctly supports those components. Statements made in the response are organized, unambiguous, and supported explicitly but may contain a minor error or have minor omissions.
4 Good	The student demonstrates a good understanding of all the components of the question and fully and adequately supports those components. Statements made in the response are unambiguous, mostly complete, and mostly correct but may contain errors.
3 Satisfactory	The student demonstrates a basic understanding of the components of the question. Statements made in the response may be disorganized, ambiguous, incomplete, and may lack support.
2 Limited	The student demonstrates a limited understanding of the components of the question. Statements made in the response lack details, clarity, and support.
1 Poor	The student provides a solution that contains a relevant statement that begins to answer the question.
0 Insufficient	The response is incorrect and/or totally off topic.

Appendix



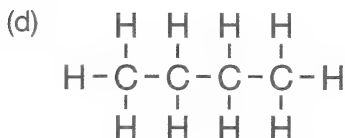
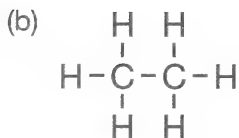
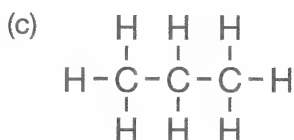
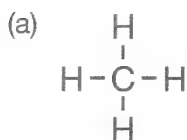
Module 6 Self-Check Answers

Contact your teacher if your answers vary significantly from the answers provided here.

Lesson 1

SC 1.

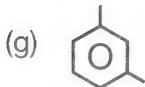
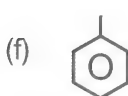
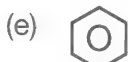
Practice 1.



Practice 2.

- Hydrocarbons containing five or six carbon atoms (e.g., pentane, C_5H_{12}) are expected to be found in naphtha.
- Naphtha is a fuel in campstoves and in some lighters.

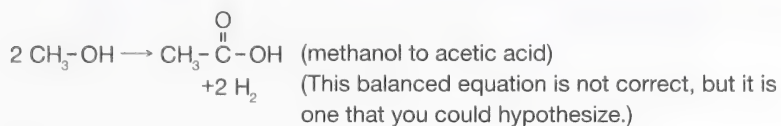
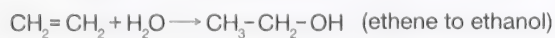
Practice 3.



SC 2.

Practice 5.

Many answers may exist; a few examples are provided.



Practice 7.

Chemical Sales in Canada



Sc 3.

Section 10.1 1.

(a) ethane	CH_3CH_3	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array}$	
(b) ethylene	CH_2CH_2	$\begin{array}{c} \text{H} \quad \quad \text{H} \\ \diagdown \quad \diagup \\ \text{C}=\text{C} \\ \diagup \quad \diagdown \\ \text{H} \quad \quad \text{H} \end{array}$	
(c) polyethylene	$[\text{CH}_2\text{CH}_2]_n$	$\left[\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ -\text{C}-\text{C}- \\ \quad \\ \text{H} \quad \text{H} \end{array} \right]_n$	$\begin{array}{cccccc} \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \\ & & & & & \\ -\text{C} & -\text{C} & -\text{C} & -\text{C} & -\text{C} & -\text{C}- \\ & & & & & \\ \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \end{array}$
(d) styrene	$\text{CH}_2\text{CCH}_6\text{H}_5$	$\begin{array}{c} \text{H} \quad \quad \text{H} \\ \diagdown \quad \diagup \\ \text{C}=\text{C} \\ \diagup \quad \diagdown \\ \text{H} \quad \quad \text{C}_6\text{H}_5 \end{array}$	
(e) polystyrene	$[\text{CH}_2\text{CCH}_6\text{H}_5]_n$	$\left[\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ -\text{C}-\text{C}- \\ \quad \\ \text{H} \quad \text{C}_6\text{H}_5 \end{array} \right]_n$	$\begin{array}{cccccc} \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \\ & & & & & \\ -\text{C} & -\text{C} & -\text{C} & -\text{C} & -\text{C} & -\text{C}- \\ & & & & & \\ \text{H} & \text{C}_6\text{H}_5 & \text{H} & \text{C}_6\text{H}_5 & \text{H} & \text{C}_6\text{H}_5 \end{array}$
(f) vinyl chloride	CH_2CHCl	$\begin{array}{c} \text{H} \quad \quad \text{H} \\ \diagdown \quad \diagup \\ \text{C}=\text{C} \\ \diagup \quad \diagdown \\ \text{H} \quad \quad \text{Cl} \end{array}$	
(g) polyvinyl chloride	$[\text{CH}_2\text{CHCl}]_n$	$\left[\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ -\text{C}-\text{C}- \\ \quad \\ \text{H} \quad \text{Cl} \end{array} \right]_n$	$\begin{array}{cccccc} \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \\ & & & & & \\ -\text{C} & -\text{C} & -\text{C} & -\text{C} & -\text{C} & -\text{C}- \\ & & & & & \\ \text{H} & \text{Cl} & \text{H} & \text{Cl} & \text{H} & \text{Cl} \end{array}$
(h) ethylene glycol	$\text{CH}_2\text{OHCH}_2\text{OH}$	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{H} \\ \quad \\ \text{O} \quad \text{O} \\ \quad \\ \text{H} \quad \text{H} \end{array}$	
(i) ethylene dichloride	$\text{CH}_2\text{ClCH}_2\text{Cl}$	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{H} \\ \quad \\ \text{Cl} \quad \text{Cl} \end{array}$	

SC 4.

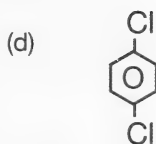
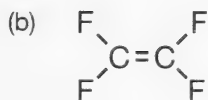
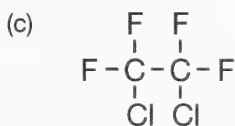
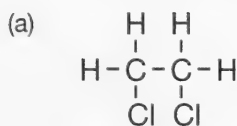
Section 10.1 2.

- For every 11 jobs in an ethane plant, 17 700 potential jobs are created.
- When ethane-containing natural gas is exported, the jobs in the ethane plant and those generated by the multiplier effect are also exported.
- The cost of ethane to plants will increase as will the cost of ethane products to consumers. The reduced availability of ethane will result in a lower supply of products made from ethane, possibly further increasing the price of the products. The high cost of these products would eventually result in a lowered demand for them and, therefore, job losses in the industry.

Lesson 2

SC 1.

Practice 1.



Practice 2.

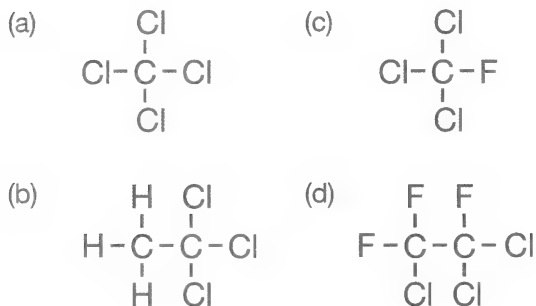
- triiodomethane
- 3-chloromethylpropene
- dichloromethane
- 1,2,3-tribromopropane
- chlorobenzene
- phenylethene

You might have used names that contain redundancies; these are still correct. For example, 3-chloro-2-methylprop-1-ene is acceptable for b. above.

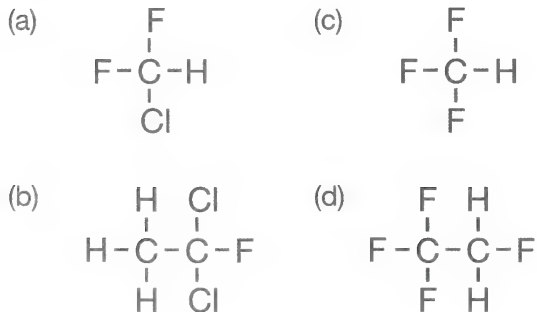
Practice 3.

- a. Chloroethene has a higher boiling point than ethene because it has stronger intermolecular forces. Firstly, it is polar so it exhibits dipole-dipole forces. Secondly, it has more electrons so its London forces are stronger.
- b. Chloroethene is likely more soluble than ethane because it is polar and water is a polar solvent.

Practice 4.



Practice 5.



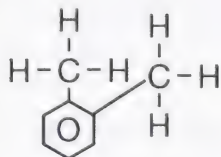
SC 2.

- 4.b. 1,1,1-trichloroethane
- 4.c. trichlorofluoromethane
- 4.d. 1,1,2-trichloro-1,2,2-trifluoroethane
- 5.a. chlorodifluoromethane
- 5.b. 1,1-dichloro-2-fluoroethane
- 5.d. 1,1,1,2-tetrafluoroethane

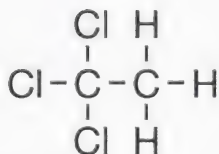
SC 3.

Practice 6.

a.

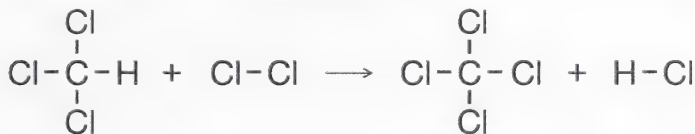


b.

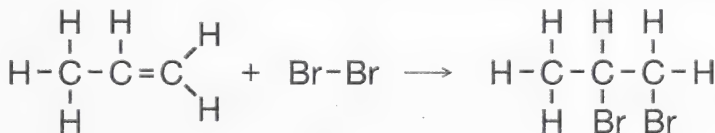


Practice 7.

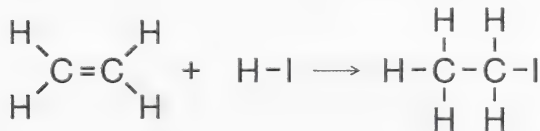
a. This produces tetrachloromethane + hydrogen chloride in a substitution reaction.



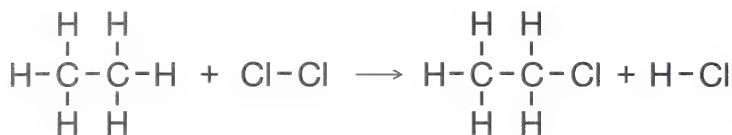
b. This produces 1,2-dibromopropane in an addition reaction.



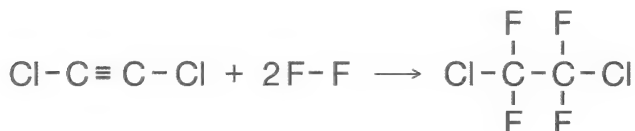
c. This produces iodoethane in an addition reaction.



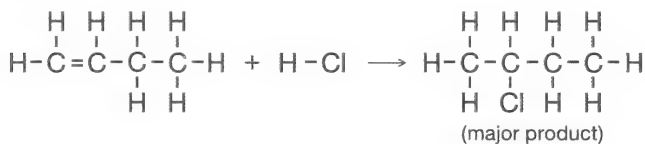
- d. This produces chloroethane + hydrogen chloride in a substitution reaction.



- e. This produces 1,2-dichloro-1,1,2,2-tetrafluoroethane in an addition reaction.

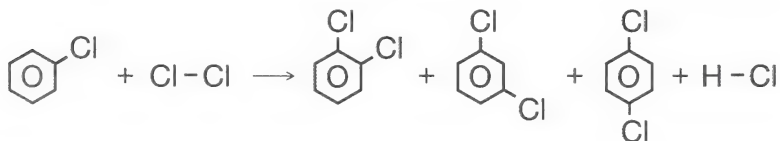


- f. This produces 2-chlorobutane in an addition reaction.



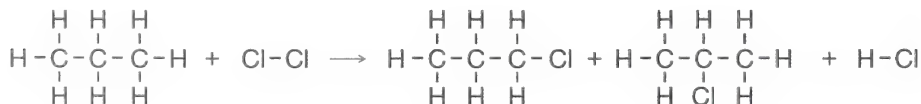
Don't worry if you showed both 2-chlorobutane and 1-chlorobutane. As illustrated in the example on page 420 of the textbook, which shows the addition to propene, the 2-chloro isomer predominates.

- g. This produces 1,2-dichlorobenzene + 1,3-dichlorobenzene + 1,4-dichlorobenzene + hydrogen chloride in a substitution reaction.

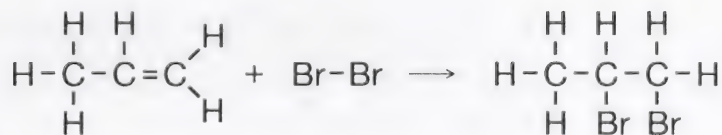


Practice 8.

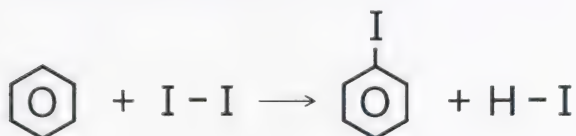
- a. This is a substitution reaction.



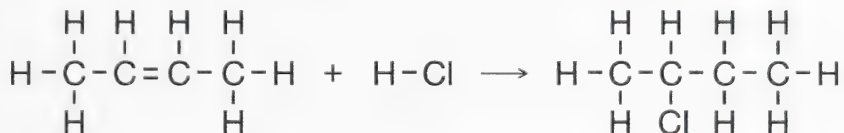
- b. This is an addition reaction.



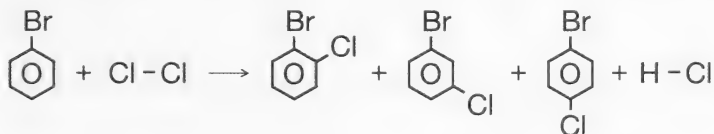
- c. This is a substitution reaction.



- d. This is an addition reaction.



- e. This is a substitution reaction.



Practice 9.

- First, carry out an addition reaction using ethene and chlorine to produce 1,2-dichloroethane. Next, carry out a substitution reaction using the 1,2-dichloroethane and chlorine. The organic product will be the desired 1,1,2-trichloroethane.
- Chemical processes are invented as a means of carrying out reactions in order to synthesize desired substances.
- Ecological, economic, political, legal, and ethical perspectives should be taken into account when inventing a new technology.

Practice 10.

Both molecules have the same number of electrons and both exhibit dipole-dipole forces due to their polarity. In this case, molecular shape is the determining factor. The 2-bromopropane molecule is more compact and doesn't make as much surface contact with its neighbours as compared to the more "stretched-out" 1-bromopropane molecules.

Practice 11.

- a. Ethical or social—the statement identifies the importance of society and human lives.
- b. Technological—the statement identifies technological uses of these substances.
- c. Scientific—the statement describes a research process and implies a scientific method and reliance on data, including the interpretation and evaluation of data.
- d. Economic—the statement identifies the monetary aspect of pesticide use.
- e. Political—the statement makes reference to a political process.
- f. Legal—the statement makes reference to laws and legislation.
- g. Ethical and ecological—the statement identifies that it would have been most appropriate to inform people and to allow them to make a decision about whether to be exposed to organic halides. The statement also references the carcinogenic nature of some organic halides.
- h. Social and ecological—the statement references societal action and a program that reduces the quantity of plastics in landfills.

Lesson 3

SC 1.

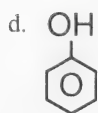
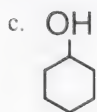
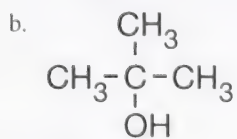
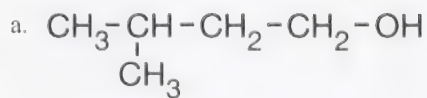
Practice 4.

Because volatility is inversely proportional to the strength of intermolecular forces, the order of increasing volatility is: alcohols, organic halides, hydrocarbons.

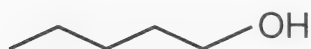
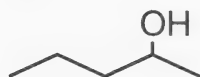
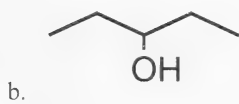
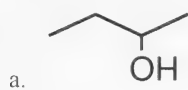
Practice 5.

- a. butan-2-ol
- b. pentan-2-ol
- c. cyclohexane-1,3-diol

Practice 6.



Practice 7.



Practice 8.

Methanol (CH_3OH , 18 electrons) exhibits London forces, dipole-dipole forces, and hydrogen bonding. Methane (CH_4 , 10 electrons) has weaker London forces than methanol and exhibits no dipole-dipole forces or hydrogen bonding. Theories suggest that the intermolecular attractive forces influence the boiling point. Methanol, having stronger intermolecular forces, should therefore have a higher boiling point.

Practice 9.

- The order is ethane (C_2H_6 , 18 electrons), fluoromethane (CH_3F , 18 electrons), methanol (CH_3OH , 18 electrons). Each compound has similar London forces, but fluoromethane has dipole-dipole forces and methanol has dipole-dipole forces and hydrogen bonding.
- The order is pentane (C_5H_{12} , 42 electrons), 1-chlorobutane ($\text{C}_4\text{H}_9\text{Cl}$, 50 electrons), butan-1-ol ($\text{C}_4\text{H}_9\text{OH}$, 42 electrons). Pentane has only London forces. The other two have London forces and dipole-dipole forces. Even though the London forces in 1-chlorobutane are slightly stronger than those of butan-1-ol, this is more than offset by the fact that butan-1-ol is the only compound exhibiting hydrogen bonding.

Practice 10.

With its three O-H bonds, glycerol forms strong hydrogen bonds with water molecules. This makes it more difficult for water molecules to come together in the correct arrangement to form crystals. Therefore, a lower temperature is needed to cause freezing.

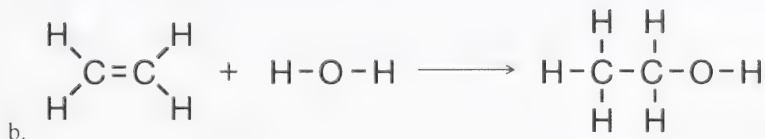
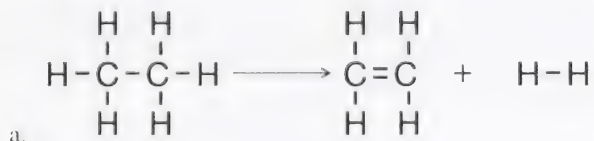
Practice 11.

- Ethane (C_2H_6 , 18 electrons) has the lowest boiling point because it only exhibits London forces. Chloroethane ($\text{C}_2\text{H}_5\text{Cl}$, 34 electrons) has a boiling point between those of ethane and ethanol because it has stronger London forces than ethane and has dipole-dipole forces. Ethanol ($\text{C}_2\text{H}_5\text{OH}$, 26 electrons) has the highest boiling point because, even though it has weaker London forces than chloroethane, it exhibits hydrogen bonding.
- Ethanol has the greatest solubility because, like the solvent water, ethanol is a small, polar, hydrogen-bonded substance. Chloroethane has slight solubility because it is a small, polar molecule. Ethane is the least soluble because it has no polarity or hydrogen bonding.

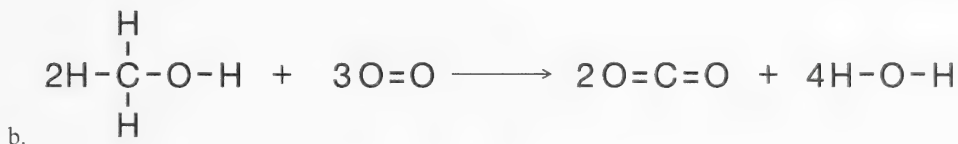
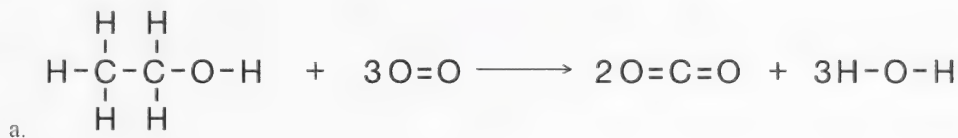
Practice 12.

- $\text{CH}_4(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightarrow \text{CO}(\text{g}) + 3 \text{H}_2(\text{g})$
- $\text{CO}(\text{g}) + 2 \text{H}_2(\text{g}) \rightarrow \text{CH}_3\text{OH}(\text{l})$

Practice 13.



Practice 14.



Practice 15.

a.

$$\begin{aligned} 5.0\% \text{ of } 355 \text{ mL} &= (0.050)(355 \text{ mL}) \\ &= 18 \text{ mL ethanol} \end{aligned}$$

b.

$$\begin{aligned} 12\% \text{ of } 150 \text{ mL} &= (0.12)(150 \text{ mL}) \\ &= 18 \text{ mL ethanol} \end{aligned}$$

c.

$$\begin{aligned} 40\% \text{ of } 45 \text{ mL} &= (0.40)(45 \text{ mL}) \\ &= 18 \text{ mL ethanol} \end{aligned}$$

d. Each drink has the same alcohol content.

Practice 16.

Economic perspective: The government generates enormous tax revenues from alcoholic beverages. Denaturing industrial alcohol prevents people from obtaining alcohol without paying the tax.

Societal perspective: If not denatured, alcohol would be more easily obtained, likely increasing alcoholism and consumption by minors.

Practice 17.

The relative boiling points should increase in this order: methanol (CH_3OH , 18 electrons), ethanol ($\text{C}_2\text{H}_5\text{OH}$, 26 electrons), propan-1-ol ($\text{C}_3\text{H}_7\text{OH}$, 34 electrons), butan-1-ol ($\text{C}_4\text{H}_9\text{OH}$, 42 electrons).

All four compounds exhibit London forces, dipole-dipole forces, and hydrogen bonding. The order given corresponds to the fact that the London forces, and hence the boiling points, increase with the increasing number of electrons.

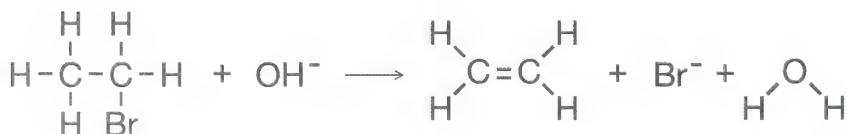
The boiling points are 64.7°C , 78.4°C , 97.1°C , and 117.7°C for methanol, ethanol, propan-1-ol, and butan-1-ol respectively.

Evaluation: The prediction is judged to be verified by the literature values.

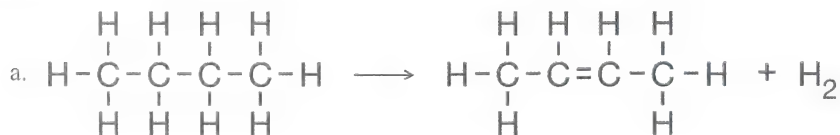
Contact your teacher if your answers vary significantly from the answers provided here.

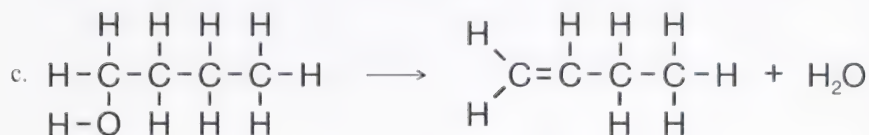
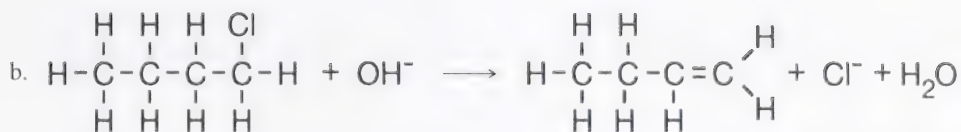
SC 2.

Practice 18.

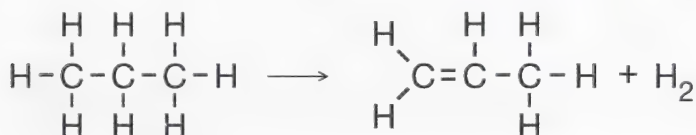


Practice 19.

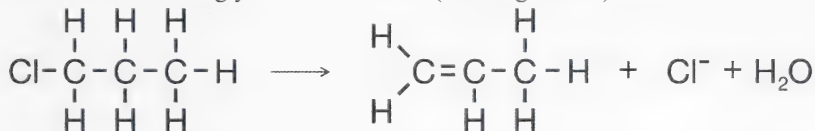


**Practice 20.**

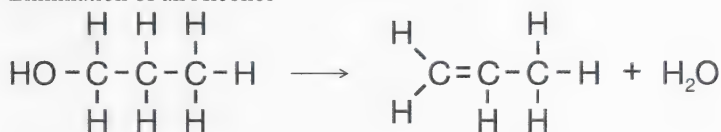
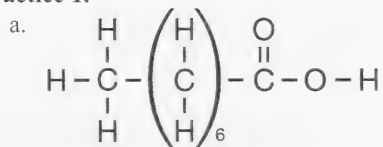
Cracking of Propane



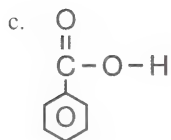
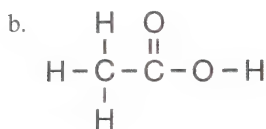
Elimination in Strongly Basic Conditions (Dehalogenation)



Elimination of an Alcohol

**Lesson 4****SC 1.****Practice 1.**

Petrochemicals



Practice 2.

- methanoic acid (you may hear the common name “formic acid”)
- pentanoic acid (you may hear the common name “valeric acid”)
- hexanoic acid (you may hear the common name “caproic acid”)

SC 2.

Practice 4.

- ethyl propanoate (from propanoic acid and ethanol)
- methyl butanoate (from butanoic acid and methanol)
- butyl methanoate (from methanoic acid and butan-1-ol)
- propyl ethanoate (from ethanoic acid and propan-1-ol)

If you got the two fragments backwards when you named the esters in this question (e.g., propyl ethanoate for part a above), try writing the full structural formula for each—it will help you get the name right.

Practice 5.

- As shown in “Table 2” on page 439 of the textbook, the ester is pentyl butanoate. The acid required is butanoic acid and the alcohol needed is pentan-1-ol.
- As shown in the same table, the ester is octyl ethanoate. The acid required is ethanoic acid and the alcohol needed is octan-1-ol.

Practice 6.

- For each class of compounds, as the molar mass increases so does the number of electrons. The increase in the number of electrons strengthens the London forces attracting the molecules to each other, thus increasing the boiling point.
- The alkanes exhibit only London forces. Even though the esters are polar and have dipole-dipole forces as well as London forces, the effect is negligible in large molecules where only the small area around the oxygen atoms is polar.

- c. Of the three classes, only the carboxylic acids contain the O-H bond. Because this feature gives them hydrogen bonding, these compounds have stronger intermolecular bonding and, therefore, higher boiling points.
- d. Yes. Knowledge of London forces, dipole-dipole interactions, and hydrogen bonding explain the observed properties.
- e. The effect of molecular shape on London forces must be considered in branched-chain structures.
- f. The line for alcohols would fall between those of methyl esters and carboxylic acids.
- g. The prediction in part f is verified. (If you made the wrong prediction, check that you remembered that alcohols have H-bonding.)

SC 3.

Reaction	Alcohol	Carboxylic Acid	Ester
1	ethanol (C ₂ H ₆ O)	ethanoic acid (C ₂ H ₄ O ₂)	ethyl ethanoate (C ₄ H ₈ O ₂)
Molecular Mass	46.08 g/mol	62.08 g/mol	89.13 g/mol
Atom Economy	$= \frac{89.13 \text{ g/mol}}{(46.08 \text{ g/mol} + 62.08 \text{ g/mol})}(100)$ $= 82.41\%$		
2	propan-1-ol (C ₃ H ₈ O)	methanoic acid (CH ₂ O ₂)	propyl methanoate (C ₄ H ₈ O ₂)
Molecular Mass	60.11 g/mol	30.03 g/mol	88.12 g/mol
Atom Economy	$= \frac{88.12 \text{ g/mol}}{(60.11 \text{ g/mol} + 30.03 \text{ g/mol})}(100)$ $= 97.76\%$		

Lesson 5

SC 1.

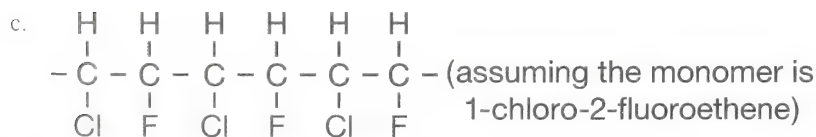
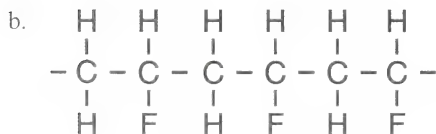
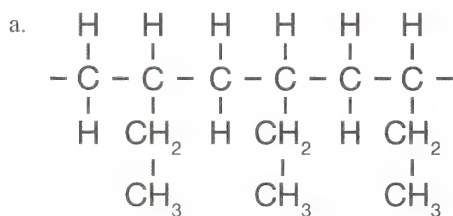
Polymer	Corresponding Monomer
polyvinyl chloride	vinyl chloride
polystyrene	styrene
polypropylene	propene
polyvinyl acetate	vinyl acetate

SC 2. All monomers have a double bond between adjacent carbon atoms. The monomers would combine through an addition reaction in which the double bond is broken and each atom is saturated by bonding to another atom (in this case, the carbon atom of another monomer with a free-bonding electron).

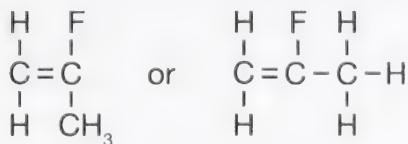
SC 3. Other possible monomers are ethylene and butadiene. Both of these substances have double bonds and could participate in addition reactions with other monomers.

SC 4.

Practice 1.



- d. The polymer in part c should be similar to Teflon but less extreme—insoluble in organic solvents, rigid, and highly resistant to heating.

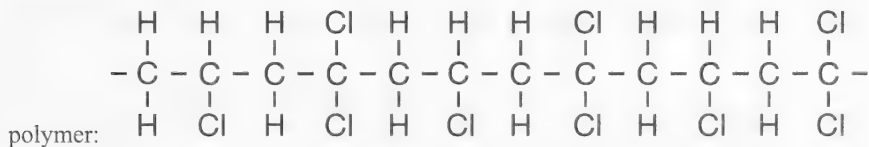
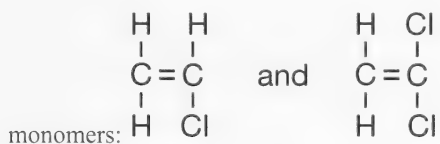
Practice 2.**Practice 3.**

- but-2-ene
- 1-chloro-1,2-difluoropropene

If you are having difficulty determining the monomer from a given addition polymer structure, write the formula for ethene; then replace the H atoms with the groups that are dangling off the polymer chain.

Practice 4.

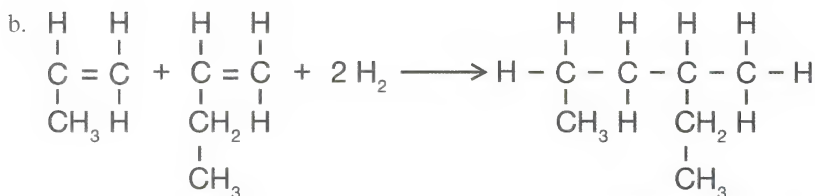
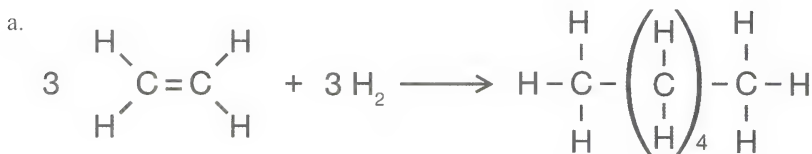
The monomer should be an alkene or alkyne.

Practice 5.**Practice 6.**

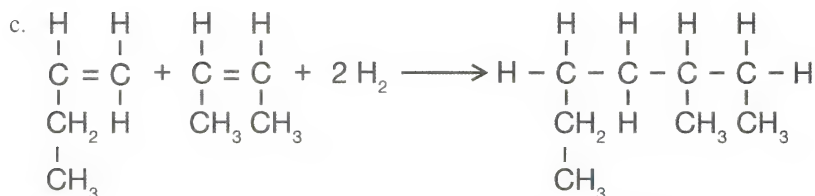
- Typical properties of a plastic are insolubility in water, good insulators of heat and electricity, flexibility, and high melting point for a molecular material.
- Within a polymer molecule there are very strong covalent intramolecular bonds. Between the polymer molecules there are always intermolecular London forces. Depending on the structure of the polymer, there may also be dipole-dipole forces and hydrogen bonding.

- c. Plastics are flexible because the intermolecular bonds holding the polymer chains together are easily deformed. Plastics are good insulators because they are molecular, so they don't have freely moving ions or electrons. The intermolecular forces for such large molecules help explain the insolubility and high melting point of plastics.

Practice 7.



(one possible product)



(one possible product)

Practice 8.

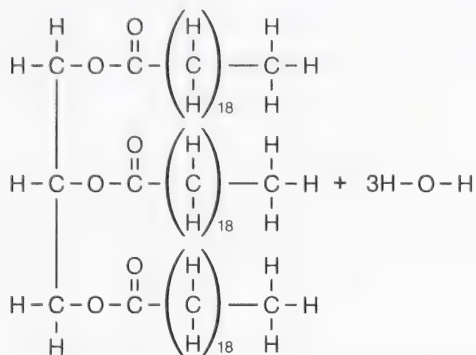
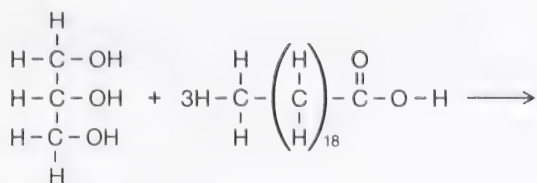
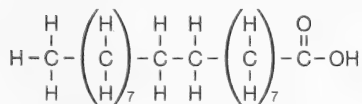
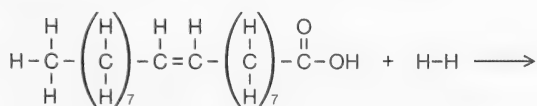
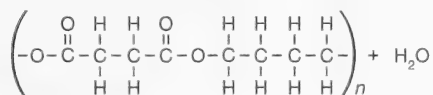
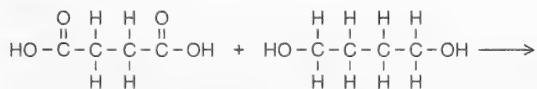
Answers will vary. Common reasons for not recycling some plastics are that there is no market for the recycled material, recycling degrades the material too much, and it is too difficult to sort the plastics.

Lesson 6

SC 1.

Practice 9.

The unsaturated lipids have a trigonal planar shape around the double bonds, making it more difficult for the molecules to aggregate into a solid. This results in lower melting points than those of the corresponding saturated lipids.

Practice 10.**Practice 11.****Practice 12.****Practice 13.**

Carboxylic acid (-COOH) and alcohol (-OH) functional groups must be present to form a polyester.

Practice 14.

The reactions to form fats and to form polyesters are similar because, in both cases, linkages are formed by “condensing out” water molecules. The reactions are different in that fats are only tri-esters, whereas polyesters contain many monomer units.

SC 2.

Practice 18.

There are hydroxyl (-OH) functional groups present in glucose and fructose molecules.

Practice 19.

Cellulose and starch are polysaccharides. The rigid, layered structure of cellulose provides support to plants and plant cells. Because its single chains are small enough to be soluble and mobile, starch serves as a means of storing and transporting energy in plants.

Practice 20.

- a. Sugars are small molecules and are readily soluble because of strong intermolecular bonding with solvent water molecules. Starch is a polymer of the simple sugar glucose. While starch’s helical shape and single-strand structure allow it to be soluble, it is not as soluble as sugars.
- b. Cellulose has a different structure than starch. Cellulose is composed of linear polymer chains that can align side by side and favour interchain hydrogen bonding, thus creating a rigid, inflexible structure.

Practice 21.

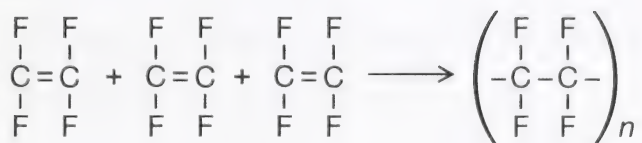
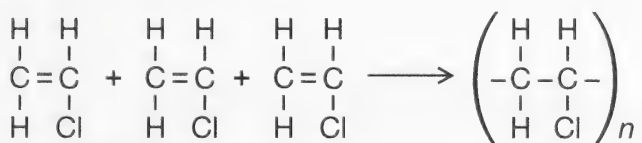
Carbohydrate molecules can be recognized by their ring structure, which has an oxygen atom in the ring and numerous hydroxyl (-OH) groups attached to the ring.

Practice 22.

Sugar molecules form stronger intermolecular bonds than do hydrocarbons because of their polarity and ability to hydrogen bond. The shape of sugar molecules also allows them to readily fit into a crystal lattice.

Practice 23.

Glucose is highly soluble, starch is slightly soluble, and cellulose is insoluble. Glucose is highly soluble because it is a small, polar, hydrogen-bonded compound that readily forms intermolecular bonds with water molecules. Although starch is a polymer, its single chains are small enough to be water-soluble. Also a polymer, cellulose is insoluble because of its bulky, inflexible structure made of layered sheets.

SC 3.**Section 10.5 1.****Section 10.5 2.****Section 10.5 4.**

Sample solution only; answers will vary.

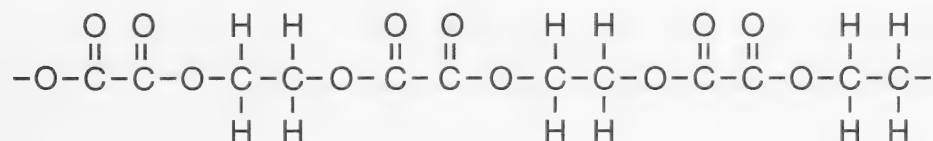
The convenience of plastic bags, packaging, and water pipes makes these products a beneficial use of polyethylene (polyethene). Problems arise from the disposal of these products. These products take up a lot of space in landfills and often end up in oceans and lakes where they are a serious hazard to marine life. Using biodegradable plastics and reusable cloth bags would help reduce these problems.

Section 10.5 5.

Responses will vary. Remember to add the information you collect to your course folder.

Section 10.5 6.

Nylon toothbrushes are less expensive than “natural” toothbrushes and are more durable. However, nylon toothbrushes are not biodegradable, and it may be true that they harbour a lot of germs because they last for such a long time.

Section 10.5 7.

Section 10.5 8.

- a. Pasta, containing the polysaccharide starch, has the synthetic analog cellulose triacetate, also a polysaccharide.
- b. Meat, containing the polyamide protein, has the synthetic analog nylon, also a polyamide.
- c. Butter, containing the “polyester” fat, has the synthetic analog Dacron, a polyester fabric.

Section 10.5 9.

- a. Desirable properties of a polymer used for potting material are the polymer's ability to absorb many times its own weight in water and to make the absorbed nutrients available to the plants.
- b. To test water absorption capacity, one could soak equal masses of the two polymers in water, filter each mixture to drain off excess water, and then reweigh the polymers. The mixture with the greater mass would be the best one with regards to absorption capacity.

To test the ability to release nutrients, one could grow several identical plants in two identical containers, each filled with a different polymer. The polymer with the plant that grew the best over time would be the best one with regards to the ability to release nutrients.

Section 10.5 10.

Sample solution only; answers will vary as these are opinions and there can be no right or wrong answer.

Organic usually refers to how food is grown or raised. Organic products are generally healthy and environmentally friendly, so the term is valid.

Natural normally describes something as it occurs in nature. An example of the term's use is “natural spring water” as opposed to tap water. The term is not very meaningful and so may not be valid.

Chemical is associated with synthetic products like artificial sweeteners. The word *chemical* in this context has negative connotations and is usually avoided in advertising consumer goods. It may not always be valid to interpret *chemical* negatively.

Section 10.5 11.

Starch is metabolized by humans and so has food value. Cellulose, on the other hand, cannot be metabolized by humans because their digestive systems do not have the necessary enzymes to break cellulose down. Because of this, cellulose has virtually no food value.

Section 10.5 12.

Sugars are very water-soluble in sap because they are relatively small molecules, are polar, and exhibit hydrogen bonding. Wood is primarily cellulose, a polymer whose rigid structure of layered sheets makes it insoluble.

Section 10.5 13.

Plastic bags are superior in some ways to paper bags. The polymer structure of the plastic is stronger than the polymer structure of the fibres in the paper. Plastic bags are also lighter and cheaper than paper bags. However, paper bags are more eco-friendly than plastic bags because they are biodegradable.

Section 10.5 14.

- a. addition
- b. condensation
- c. condensation
- d. condensation

